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MONTE CARLO CALCULATION OF NEUTRON STREAMING THROUGH TWO-LEGGED-DUCT ENTRANCEWAYS

June 1965

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

MONTE CARLO CALCULATION OF NEUTRON STREAMING THROUGH TWO-LEGGED-DUCT ENTRANCEWAYS

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Type C

by

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ABSTRACT

Several techniques for calculating dose rates in the study of shelter entranceways are reported herein. Calculations have been verified by experiments. These calculations also determine neutron energy spectra, a parameter that is difficult to measure and which is very useful in gaining insight into the design of protective structures. Both the neutron flux spectra and dose rates are calculated for various positions along the centerline of a two-legged duct. Calculations were performed utilizing the ADONIS computer code which solves the Neumann approximation to the transport equation by Monte Carlo techniques. These Monte Carlo calculations were compared to second-leg calculations utilizing a semiempirical albedo formula, and were also compared to experimental measurements made with a tissue equivalent dosimeter. Included is a discussion of UNIGEOM, a generalized computer program for ADONIS geometry, designed to be run on the IBM 7094.

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INTRODUCTION

The U. S. Naval Civil Engineering Laboratory has for some time experimented with the streaming of nuclear radiation through the ducted entranceways of scale-model shelters, using 14.5-Mev neutrons as source particles. This energy approximates that of the prompt neutrons released in a fusion-type detonation.

There are many techniques for calculating the dose rate of streaming neutrons, and this report compares results of the ADONIS Monte Carlo calculations with albedo calculations. All of the calculations shown have been verified by experiment. The great advantage in employing calculations is that costly and time-consuming experiments are minimized.

The work reported herein is for the case of neutrons streaming through 3 x 3-foot-square and 11 x 11-inch-square two-legged concrete ducts. The 14.5-Mev neutron source was placed just inside the duct entrance.

ADONIS COMPUTER PROGRAM

ADONIS[1] is a Monte Carlo computer program for solving the Neumann approximation to the transport equation governing neutron and gamma-ray streaming. It is written in FORTRAN II, version 2, for the IBM 7090, and ten tapes are required. ADONIS treats a problem having up to a maximum of 80 regions which, when combined, must cover all XYZ space where each region is a parallelepiped. It is important to note that the geometry diagram 1 in Appendix C of the ADONIS manual contains an error in the designation of the coordinate system. Also, it is necessary that the exit from the duct be in the positive Y direction and into the highest numbered region.

The particle flux is divided into energy groups called bins, of which a maximum of 10 is permitted. For a neutron problem, approximately seven nuclides may be used; however, for a gamma-ray problem more nuclides are possible. These nuclides must completely describe the material composition of each parallelepiped. The composition of each region may differ, but the composition within a particular region is limited to a combination of, at most, five elements.

The geometric input required for ADONIS is time-consuming and complicated to prepare, even with the aid of various computer programs designed to simplify this task. In general, the geometry must be recomputed for each change in duct configuration. In many cases all that will be changed are dimensions such as length and

width of the legs, height of the duct, and the amount of material surrounding the duct. In order to facilitate the use of ADONIS in investigating the effects of such changes in duct parameters, a computer program was written which will accept the physical characteristics of the duct and as output will yield punched cards ready for an ADONIS run. These cards consist of the bounding plane cards (BPO), adjacent region cards (IRX), complex plane cards (CMX), and horizontal and vertical plane cards (H and V). They define the geometry of ADONIS. The BPO cards give the coordinates of the maximum and minimum extent of the regions along the axes. The IRX cards define which of the regions are back to back. The CMX cards define which of the regions back to more than one region.

Although subroutines called EASYGEOM and TEST G are available to facilitate preparing the input cards to ADONIS, mistakes are easily made in geometries as complex as those associated with duct problems. To remedy this situation, a computer program, UNIGEOM, was written at NCEL. The source deck of this program is listed in Table I. This program incorporates a modified EASYGEOM program as the main routine and TEST G and its subroutines as a subroutine. The bounding plane cards required as input to EASYGEOM are calculated from the physical parameters of the duct by means of a subroutine. The UNIGEOM program allows three such subroutines. The subroutines included in this report are for a two-legged duct and three-legged coplanar and non-coplanar ducts. Other configurations may be incorporated by substituting "duct" subroutines and appropriately changing the calling sequence in the main program.

ADONIS considers the following neutron interactions: isotropic and anisotropic elastic scattering, discrete and continuous inelastic scattering, scattering by hydrogen, and the (n, 2n) reaction in beryllium absorption. The gamma portion of the ADONIS program considers the Compton scattering of photons where the photoelectric effect and pair production are regarded as absorption. Particle histories in ADONIS are terminated either when an absorption occurs, the particle is degraded below an arbitrary cut-off energy, a kill occurs due to splitting, or the particle escapes. Cross-section data used in ADONIS are called from an organized-element-data tape. A source-data tape containing the position coordinates, direction cosines, and the initial energy of the neutron or gamma-ray source is required in addition to the organized-element-data tape and the geometry-input data.

The source-data tape is generated for the case of either the point source incident radiation of neutrons or gamma rays by PSGEN, a program modified to be anisotropic; in the case of gamma rays produced by neutron interaction, the source-data tape is generated by the GASP[1] program. The input to PSGEN, which is modified to be a 2π source, describes the source as the probability that particles exist below a particular energy. The energy is evaluated for probabilities in 0.1 increments of probability from 0 to 1.0. ADONIS is called in through the IBM 7090 monitor system. ADONIS contains dump and edit procedures, selected by turning sense switch 1 "on" at the time these procedures are to be initiated. After dumping, ADONIS may be restarted. Turning sense switch 2 "on" prints on-line the particle history numbers; turning sense switches 3 and 4 "on" writes an off-line trace of each particle path on tape A3.

Particle splitting is employed to improve the efficiency of the calculation by assigning importance weights to each of the regions. Regardless of the importance selected for each region, if the ADONIS program is allowed to run for a sufficiently long time, the answers furnished by it will be approximately the same. However, in making many calculations it has been determined that the proper selection of weighting functions can significantly decrease the amount of running time required. The optimum value of importance for each region may best be selected by a semiempirical approach. First, the geometry is studied and a weight, inversely proportional to importance, is assigned to each region based upon the best knowledge of neutron or gamma-ray streaming available to the investigator. Using these values, the program is run for a short period of time, after which the calculated flux in each region is reviewed. The weight of the region is then adjusted in a way which will enhance the probability of neutrons going in the desired direction while reducing the probability of neutrons going in undesired directions.

It has been experienced that approximately five tries are necessary to optimize the weight for each region in a duct with two legs and approximately 10 tries for similar optimization in a duct with three non-coplanar legs. It should be emphasized that a proper selection of weight allows a greater percentage of computer time to be devoted to following particles of interest; thus, running time for statistically significant determinations of flux may be considerably reduced. A proper selection of importance functions and an adequate running time may be judged by comparing the standard deviation of particle flux to the flux for each energy bin and duct region. ADONIS calculates the flux and particle dose in each region. The latter is accomplished through either a fine or coarse response function. These two functions differ only in that for the fine function, the response is evaluated at the same energies used for cross sections on the element-data tape, and for the coarse function, the response is averaged over each energy bin. Also, the standard deviation of dose is evaluated only where fine response functions are used. The response function is simply a function that converts particle flux into dose such as relative biological effectiveness (RBE) for the case of neutrons.

ADONIS also provides, as output data for each region, the number of absorptions, births, degradations, and deaths; flux per energy bin; deviation of flux per energy bin; total number of reflected and transmitted particles; particle balance; absorption by element and region; and coarse dose per energy region. The neutron flux is reported as the track length per source particle per unit energy in energy interval j per unit volume for finite regions. In the case of regions infinitely bounded, the total flux is given.

Analysis of ADONIS Results

When ADONIS is restarted, each run prints only the flux and dose associated with that run, rather than the best estimate based upon total running time. It was, therefore, necessary to calculate these parameters as follows:

$$\tilde{\tilde{\phi}} = \frac{\sum_{i=1}^{n} N_i \phi_i}{\sum_{i=1}^{n} N_i}$$

$$\tilde{\tilde{\sigma}}_{\phi} = \frac{\sqrt{\sum_{i=1}^{n} (N_i \phi_i)^2}}{\sum_{i=1}^{n} N_i}$$

$$\tilde{\tilde{D}} = \frac{\sum_{i=1}^{n} N_i D_i}{\sum_{i=1}^{n} N_i}$$

$$\tilde{\tilde{\sigma}}_D = \sqrt{\sum_{j=1}^{n} \left\{ [\overline{RBE}_j (E_j) \Delta E_j]^2 \left[\left(\frac{1}{\sum_{i=1}^{n} N_i} \right)^2 \sum_{i=1}^{n} \{N_i [\sigma_{ji}(\phi)]\}^2 \right] \right\}}$$

In the case of only one run,

$$\sigma_D = \sqrt{\sum_{j=1}^{m} \{[\overline{RBE}_j (E_j) \Delta E_j]^2 [c_j(\phi)]^2\}}$$

where $\tilde{\tilde{D}}$ = best estimate of dose based upon n runs

ΔE_j = energy increment of j^{th} bin

N_i = number of histories of i^{th} run

n = number of runs

m = number of energy bins

$RBE_j(E)$ = relative biological effectiveness averaged over the energy range of the j^{th} bin

σ = standard deviation of dose for n^{th} run

$\tilde{\tilde{\sigma}}_D$ = best estimate of standard deviation of dose based upon n runs

$\sigma_j(\phi)$ = standard deviation of flux for j^{th} bin

$\tilde{\tilde{\phi}}$ = best estimate of flux based upon n runs

where D_o is the incident dose due to the total number of particles emitted by the analytically simulated neutron source. Since the analytical treatment considers these to be emitted in one hemisphere, the value of incident dose is divided by 2π, the number of steridians in a hemisphere. In actual practice, ADONIS calculates the dose per incident source particle, and thus the associated value of incident dose is one source particle multiplied by the RBE of the source particle. This is numerically equal to the RBE of the source particle energy.

DESCRIPTION OF EXPERIMENTS

In experiments at NCEL, 14.5 Mev neutrons approximated the energy of neutrons released in a fusion-type detonation. Neutrons of this energy were available from a neutron generator utilizing the $T(d,n)He^4$ reaction. A two-legged duct 3 x 3 feet and a three-legged duct 11 x 11 inches were constructed for the experimental phases of this work. The latter was constructed in such a way that the orientation of the third leg could be altered to form either the coplanar or non-coplanar case. Plan and elevation drawings of these ducts, including dimensions, will be found in Figures 1, 2, and 3. The neutron source was approximated as a point source for the purpose of

calculations. In actuality, the active area of the target was a circle approximately 7/8 inch in diameter. Although this target radiated more or less isotropically, attention was taken to orient the geometry in such a way that the plane of the target was located concentric to the centerline of symmetry and perpendicular to the duct approximately one centimeter from the end of the first leg and inside the duct. The same location was used for theoretical calculations. These calculations were made for both the 3-foot and the 11-inch duct. However, experimental measurements were made only with the 3-foot duct, since the physical size of the dosimeter significantly perturbed the flux and in certain cases simply would not fit.

There is some present concern for the statistical variation of the experimentally measured dose rates, the calibration of the instrumentation utilized, and the determination of the incident dose, D_o. Nonetheless, it is believed that these results are certainly accurate to within an order of magnitude. Although plans exist for repeating these measurements with more care and augmenting them with measurements performed with helium and argon-methane detectors and foil activation techniques, this will not be done for some time. Such work really has little bearing upon the comparison of ADONIS calculations reported herein, since it will, in all likelihood, simply add more significance to the determinations.

While reviewing the results of Doty's[2] experiments, Song[3] observed that a semiempirical albedo formula could be utilized to fit the data. He utilized Monte Carlo results reported by Ballistic Research Laboratory[4] in order to determine the constants of his formula. He then calculated the dose in the second leg of the 3-foot duct and found it to be in good agreement with Doty's experimentally measured values. While it is true that many different functions could undoubtedly fit Doty's data, a physical explanation of neutron streaming can be easily made utilizing albedo concepts. This was the motivating reason behind the albedo development for neutron streaming through ducts. For additional validity, Song calculated the dose in the second leg of the 11-inch duct, and the ADONIS program was utilized to determine the dose in both ducts by Monte Carlo calculations of the Neumann approximation to the transport equation.

MONTE CARLO CALCULATIONS

The program UNIGEOM (Table I), was written to calculate ADONIS input geometry from the physical parameters of the three duct configurations shown in Figures 1, 2, and 3. Since TEST G is incorporated in this program, the physical dimensions of the duct are checked for consistency, and the same diagnostics are written on the output tape as would be had EASYGEOM and TEST G been run as they were originally intended and not incorporated in the present program.

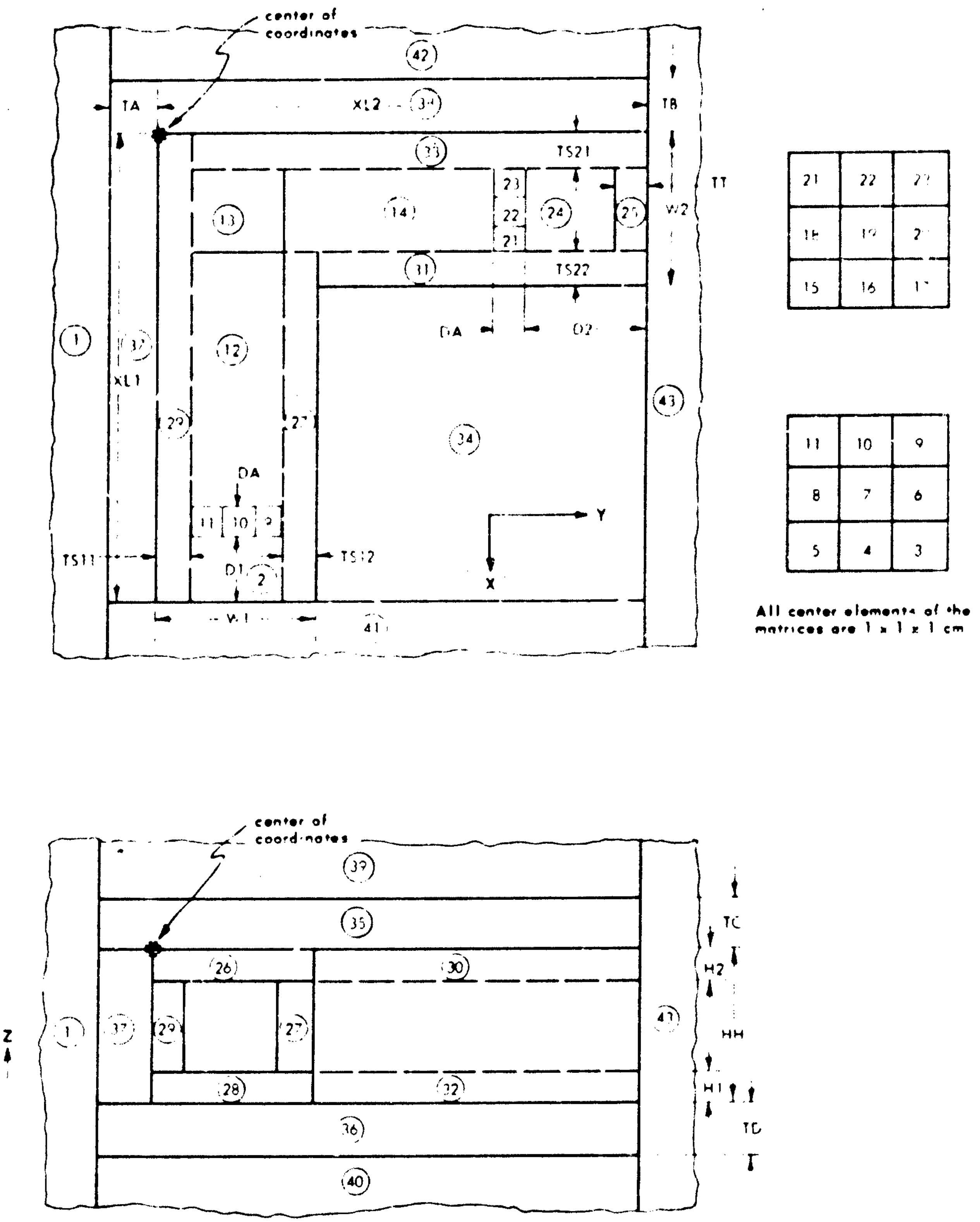


Figure 1. Two-legged duct with regions and physical parameters.

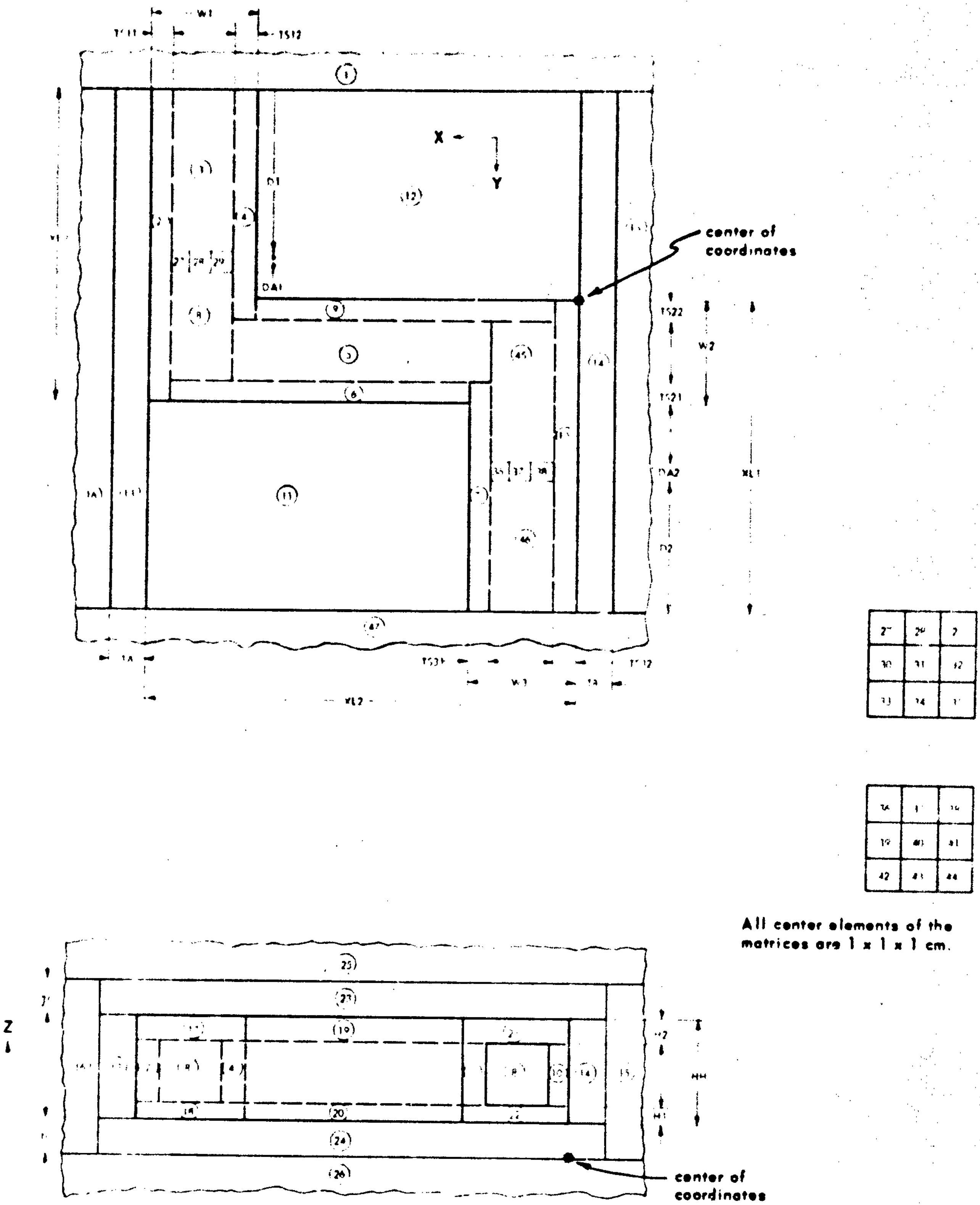


Figure 2. Three-legged coplanar duct with regions and physical parameters.

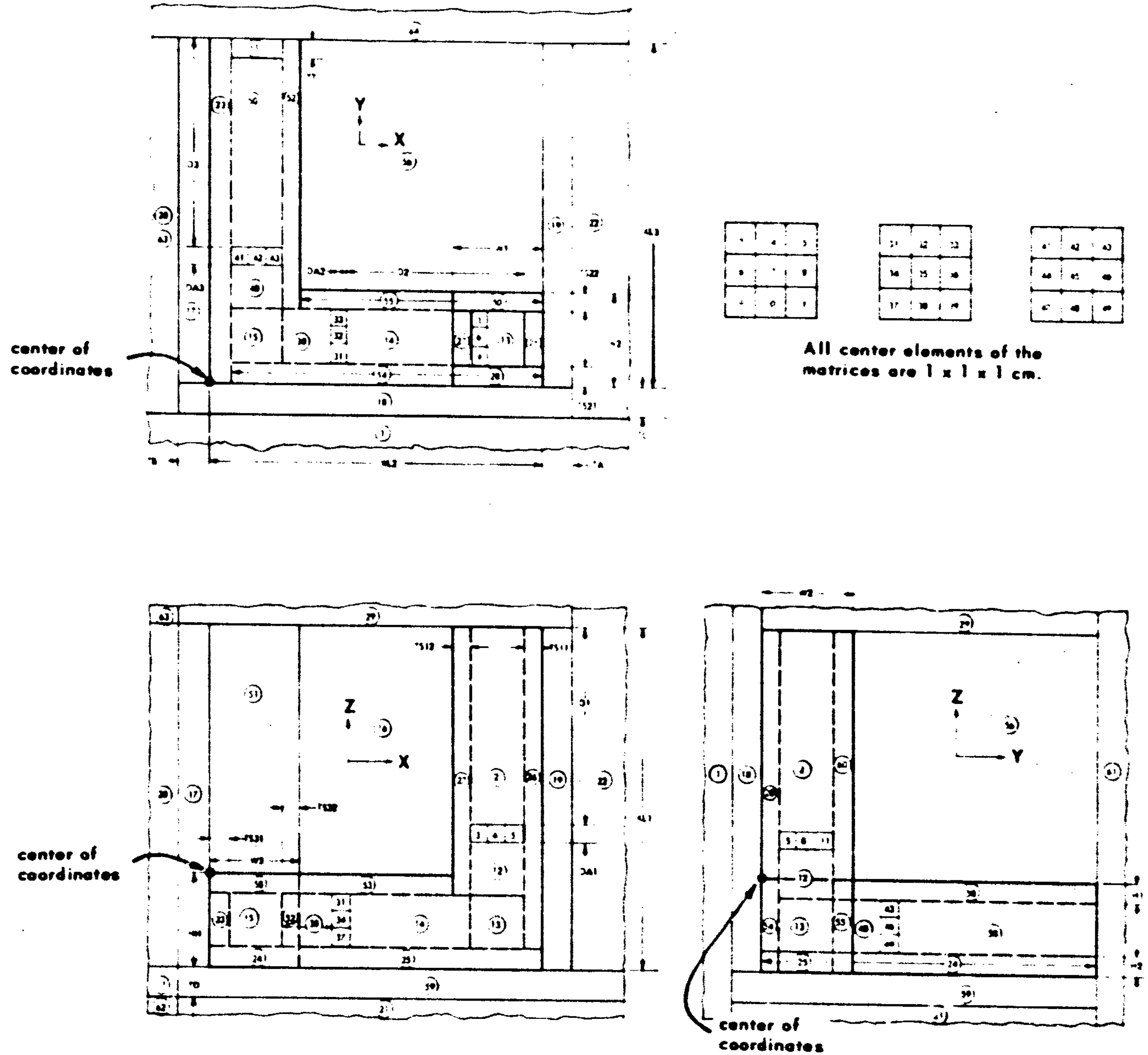


Figure 3. Three-legged non-coplanar duct with regions and physical parameters.

The appropriate geometry subroutine is indicated by a value on the first input card. Input data are read by the main program from tape A2 and are communicated to the proper routine through Common. Input data in the format F 10.5 are read in sequence XL1, XL2, XL3, W1, W2, W3, TS11, TS12, TS21, TS22, TS31, TS32, TT, D1, D2, D3, DA, DB, DC, DA1, DA2, DA3, TA, TB, TC, TD, HH, H1, H2, XX. Table II lists the values of these parameters for each of the three duct configurations. In some cases these values are zero, but for proper sequencing must be provided. All dimensions are given in centimeters to be consistent with ADONIS. The various regions in the duct are also identified in Figures 1, 2, and 3. It will be noted that a matrix of nine regions cuts each important leg in the duct. The center region of this matrix is an area 1 centimeter square and may be utilized as a detector region useful for comparing calculations to experimental dosimetry at a point. The geometry coordinates of the subroutine calculations are written as X(A, B), where A has the value given in the following table.

Coordinate	Coordinate Number
-X	1
+X	2
-Y	3
+Y	4
-Z	5
+Z	6

Coordinates are indicated by X(A, B), where A is the coordinate indicator and B is the region number.

This table also compares with values in ADONIS notation. The region number is given by B. The output of UNIGEOM is written on tapes A3 and B5, the latter of which is punched as geometry cards required for ADONIS input. First the BPO cards are punched, as identified in the preceding table, one card for each region. These coordinates are punched in E 14.5; next, the cards for the coordinates of each complex plane for both horizontal (H cards) and vertical (V cards) are punched. A complex bounding plane is created for the surface of one region if it is adjacent to the surfaces of more than one other region. One or more cards is devoted to the coordinates of the horizontal and vertical fields of each complex bounding plane. The adjacent region (IRX) cards and the complex plane (CMX) cards needed for ADONIS input are also provided by the program. Should there be an error in geometry or physical dimension that prevents the calculation of geometry, various diagnostics are provided. ADONIS input cards calculated by UNIGEOM for the parameters of Table II are listed in Table III. This information is provided as sample problems.

COMPARISON OF THEORY TO EXPERIMENT

Figure 4 shows the neutron energy flux calculated by ADONIS in several regions associated with the 11-inch two-legged duct, normalized by $D_o/2\pi$. These regions may be identified by referring to Figure 1. In Figure 4 it is seen that the flux, due to source neutrons, steadily decreases with distance along the first leg. A few source neutrons are also found in region 14, the region in the second leg adjacent to the corner. These neutrons must have arrived by direct penetration, grazing the inside corner of the duct. Had it been otherwise, their energy would have been degraded because of interaction. No source neutrons are found at other regions in the second leg.

It should be noted that the flux approximates a straight line on log-log graph paper for energies lower than ~1 Mev. In order to produce the results shown in Figure 4, it was necessary to operate the 7090 computer for approximately 23 hours. Because of this long operating time and the straight-line relationship noted, it was decided that in the future ADONIS runs the energy of the low-energy cut-off point would be raised. This should result in approximately the same statistical deviation with a much shorter running time.

The dose, corresponding to the flux shown in Figure 4, is shown in Figure 5 for the same energy regions. Here, the dose has been normalized as previously described, by dividing with $D_o/2\pi$. It should be noted that the dose in the first leg falls off as an inverse square function of distance, and in the second leg the dose falls off at a much steeper rate. This corresponds to similar results obtained during gamma streaming experiments. In Figure 5 are shown the values of dose calculated utilizing Song's semiempirical albedo formula. It is seen that the agreement is good.

Also shown in Figure 5 are the Monte Carlo/Albedo calculations at two lower source-particle energies, utilizing the Oak Ridge National Laboratory code. It is seen that the ORNL results do not agree too well and are consistently high. It should be noted that the assumptions of corner lip secondary source preclude utilizing the albedo formula for the corner region and makes the results of the region adjacent to the corner somewhat questionable. In Figure 6, the value of D/D_o has been corrected to remove the effects of distance. This has been done by multiplying the normalized dose values shown in Figure 5 by the factor ℓ^n where ℓ is the length of the duct leg, and the exponent, n, is determined from the linear slope of the dose lines shown in Figure 5. If the duct were ideal and long, the figure resulting from this new calculation would ideally be a step discontinuity occurring at the corner region. Because of the small length for the duct (~140 centimeters), this idealized shape is not realized and the resultant S-shape is obtained.

In the preceding figures are seen the first collision, multiple collision, and rad tissue equivalence dose rates. In Figure 7, the flux spectrum resulting from ADONIS calculations is shown for the 3-foot duct where the leg length is longer than that for the 11-inch duct. Because of increased computer running time required for the larger

duct, the low-energy cut-off limit was increased to 1 kev and the computer running time was considerably decreased. This resulted in an increase in the standard deviation of the flux, as shown by the bounds of each of the bars comprising the histogram. This flux is very similar to that shown for the small 11-inch duct, and the slopes of the spectrum lines below 100 kev approximate those shown in Figure 4 between 100 kev and 1 Mev. There is considerable difference between the spectra shown for the large duct in Figure 7 and those shown for the small duct in Figure 4. It is felt that this could be explained by the fact that the increased length of the large duct affords a greater opportunity for neutron interaction and, thereby, degradation of energy spectra. Results from the two ducts are, however, similar.

In Figure 8 is shown the dose of the large duct, normalized as before, the dose calculations utilizing the semiempirical albedo formula of Song, the ORNL dose calculations, and the experimentally measured dose obtained by Doty. It is seen that Song's and Doty's work are in good agreement; yet their dose measurements are greater than those calculated by the ADONIS code and less than those calculated by the 05R ORNL code. It should be noted that up to this point the importance functions of the regions of the two-legged-duct problem were selected to eliminate most corner-lip diffusion.

Another Monte Carlo ADONIS calculation was performed, keeping all conditions similar to those in the previous calculation of the large duct, with the exception that the importance of the rectangular region between the two legs was now selected to allow diffusion over the entire rectangular region. The results of these calculations are shown in Figure 8 by the dashed lines. It is seen that these results lie somewhat above the results of Song and Doty and agree very well with ORNL calculations.

In Figure 9 is shown the dose corrected for fall-off because of length. This is done by multiplying the dose of Figure 9 by ℓ^n as before. Here, the effect of the corner is more prominent, and the resulting curves more closely approximate the ideal step function. It thus appears that it is necessary to carefully consider the size of the corner lip secondary source for albedo calculations and, indeed, possibly include some diffusion effects. A great deal of caution should be exercised in fitting formulas, because when the standard deviations of the data are large — as found both experimentally and theoretically — it is usually possible to obtain what appears to be a good least-squares fit with almost any curve. On the other hand, it also appears that it is incorrect to assume maximum diffusion through the rectangular region; rather, it is believed that a more involved type of interaction is occurring between the two effects and that such interaction could be approximated by selecting the appropriate importance function for the rectangular region adjacent to both legs. Again, calculations which would verify this conclusion were not within the scope of the present work.

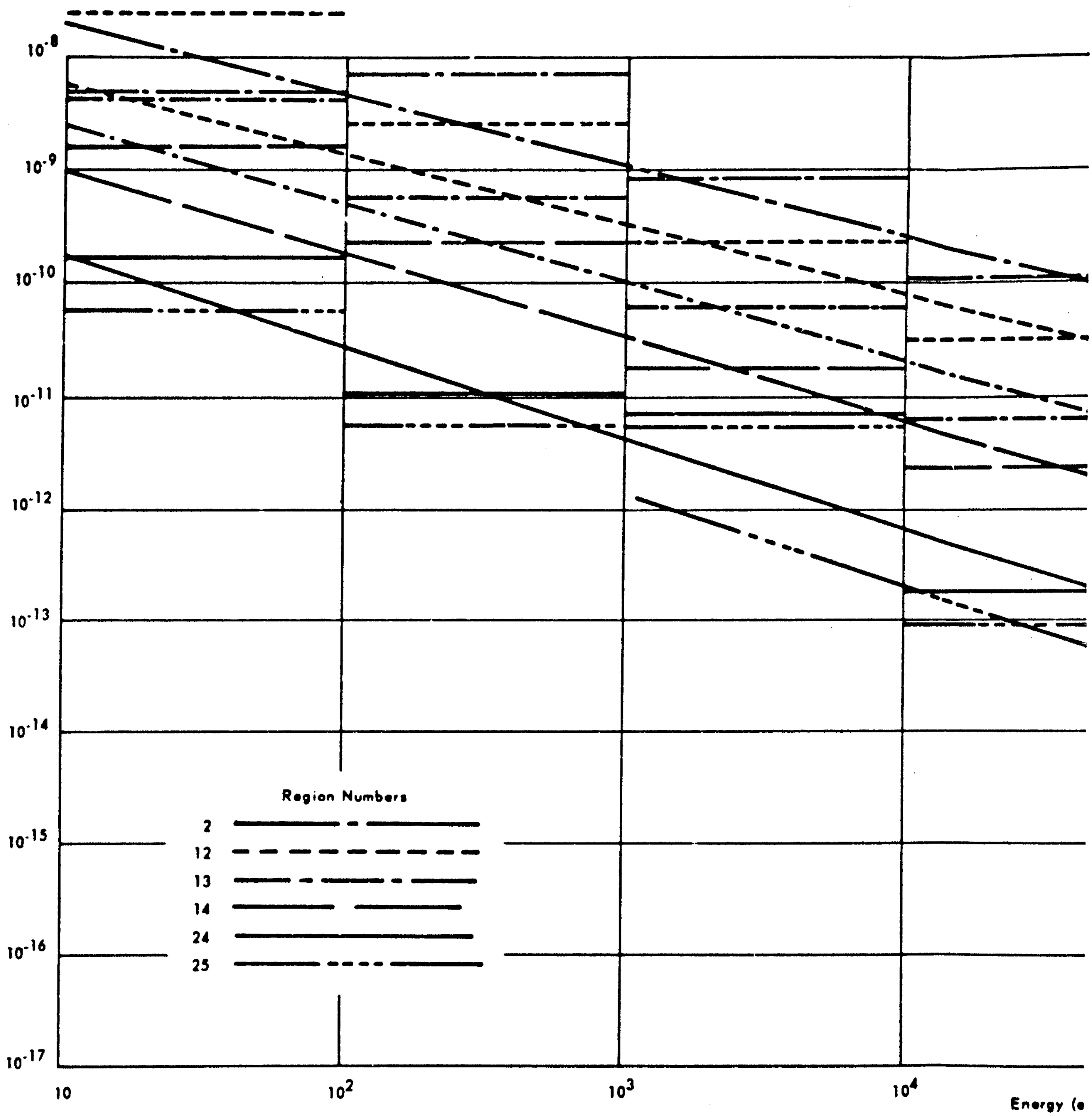
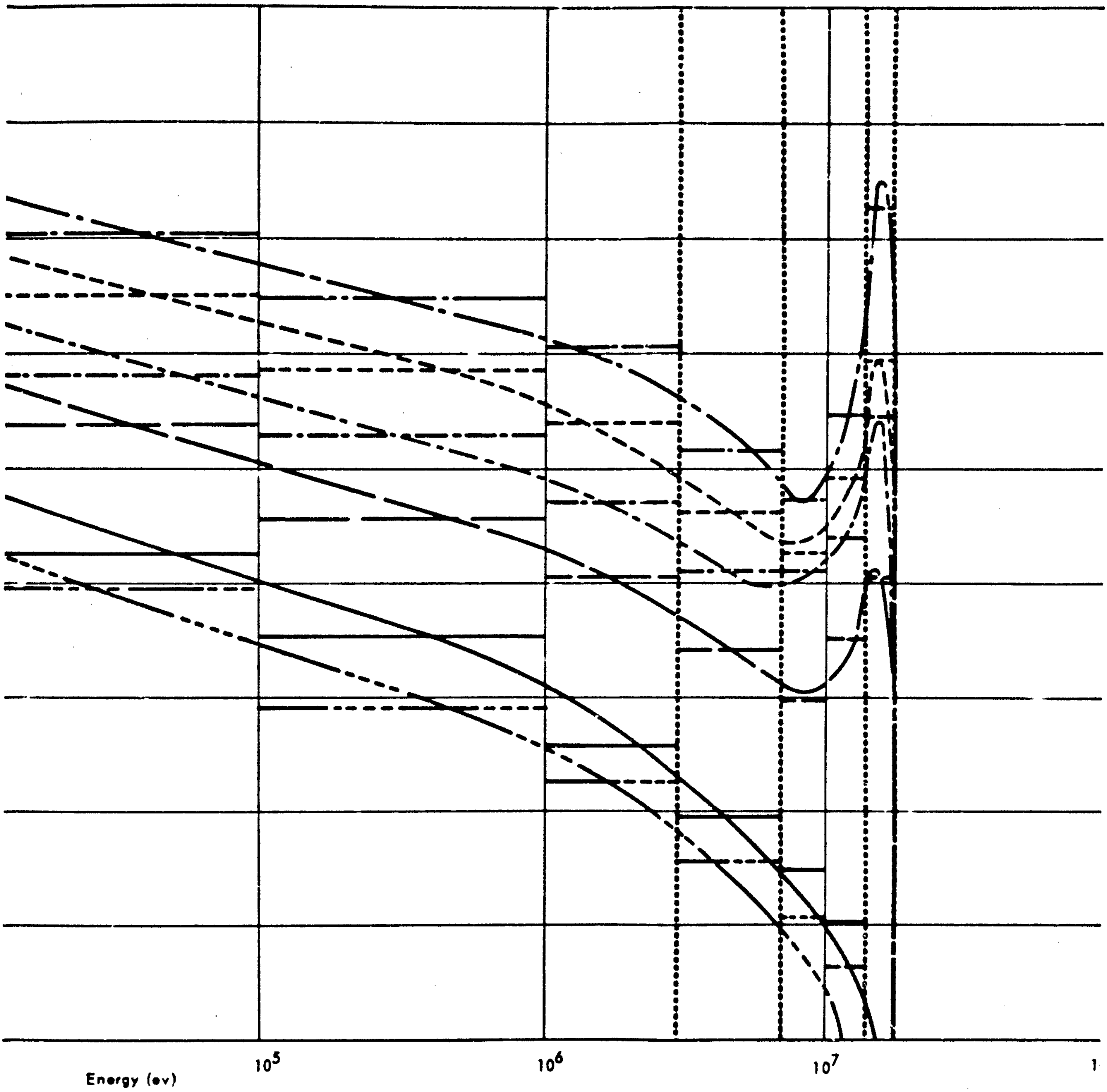


Figure 4. 11 x 11-inch duct



x 11-inch duct, neutron flux spectrum.

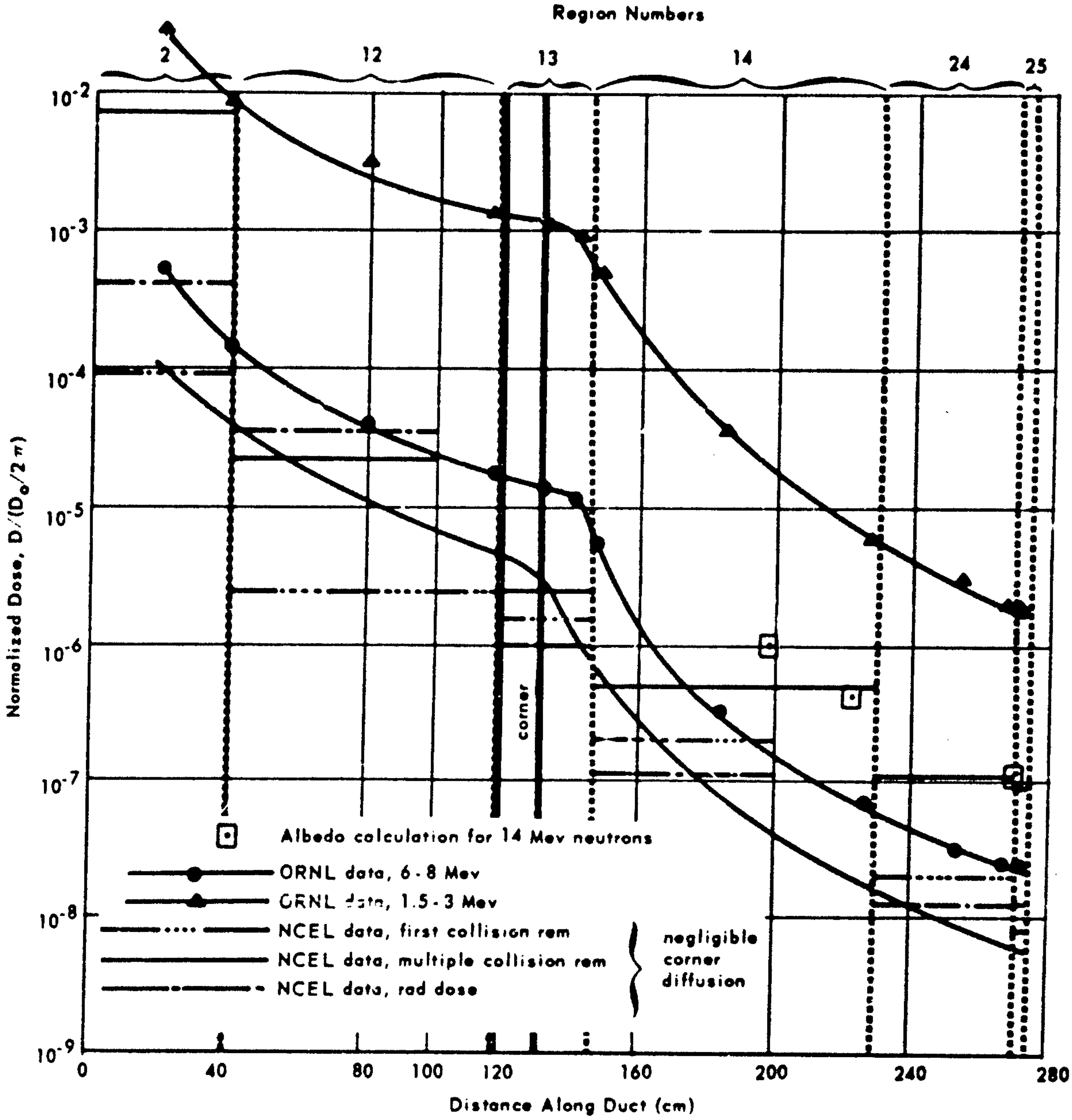


Figure 5. 11 x 11-inch duct, normalized neutron dose.

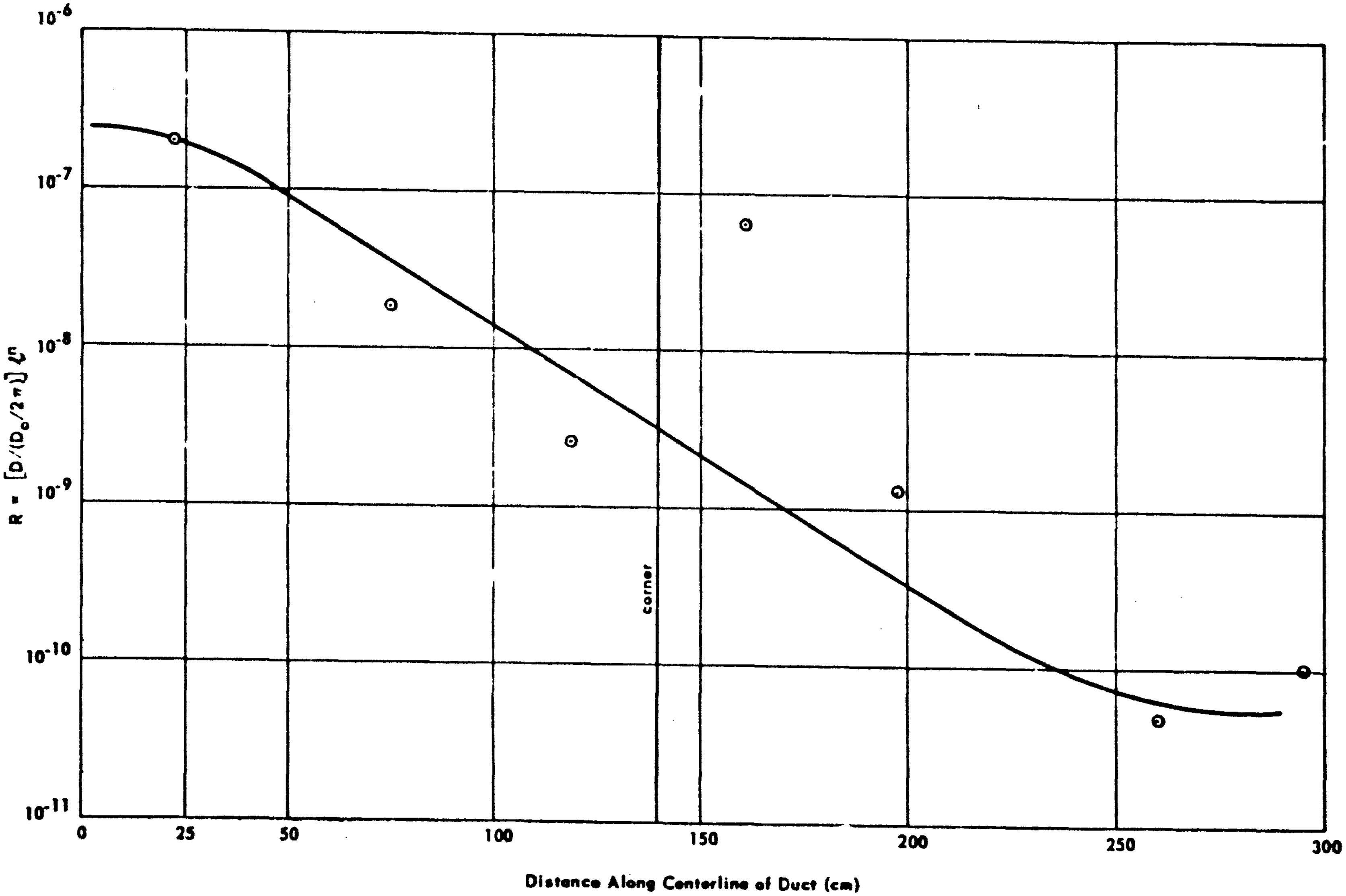


Figure 6. 11 x 11-inch duct, dose versus distance.

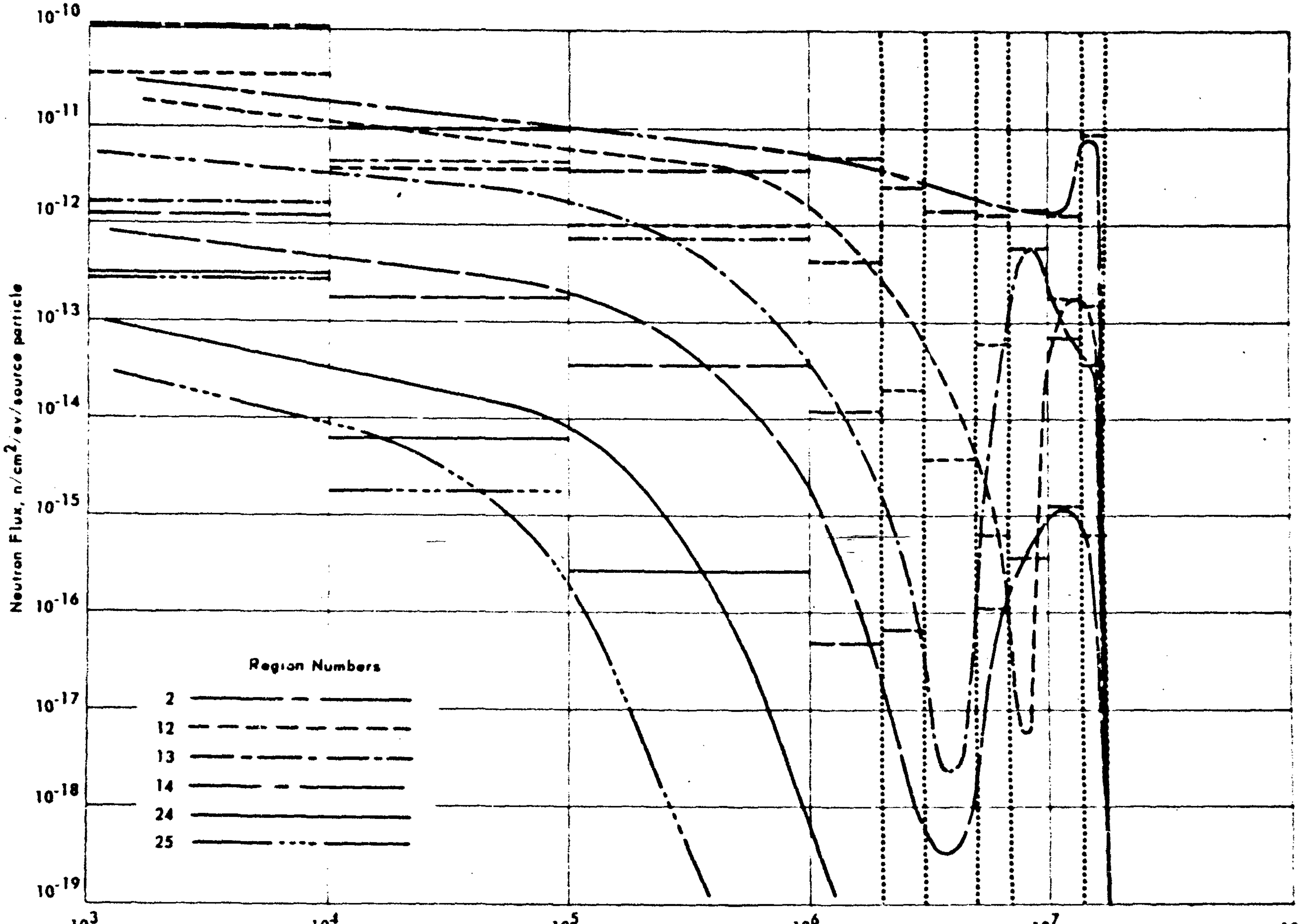


Figure 7. 3 x 3-foot duct, neutron flux spectrum.

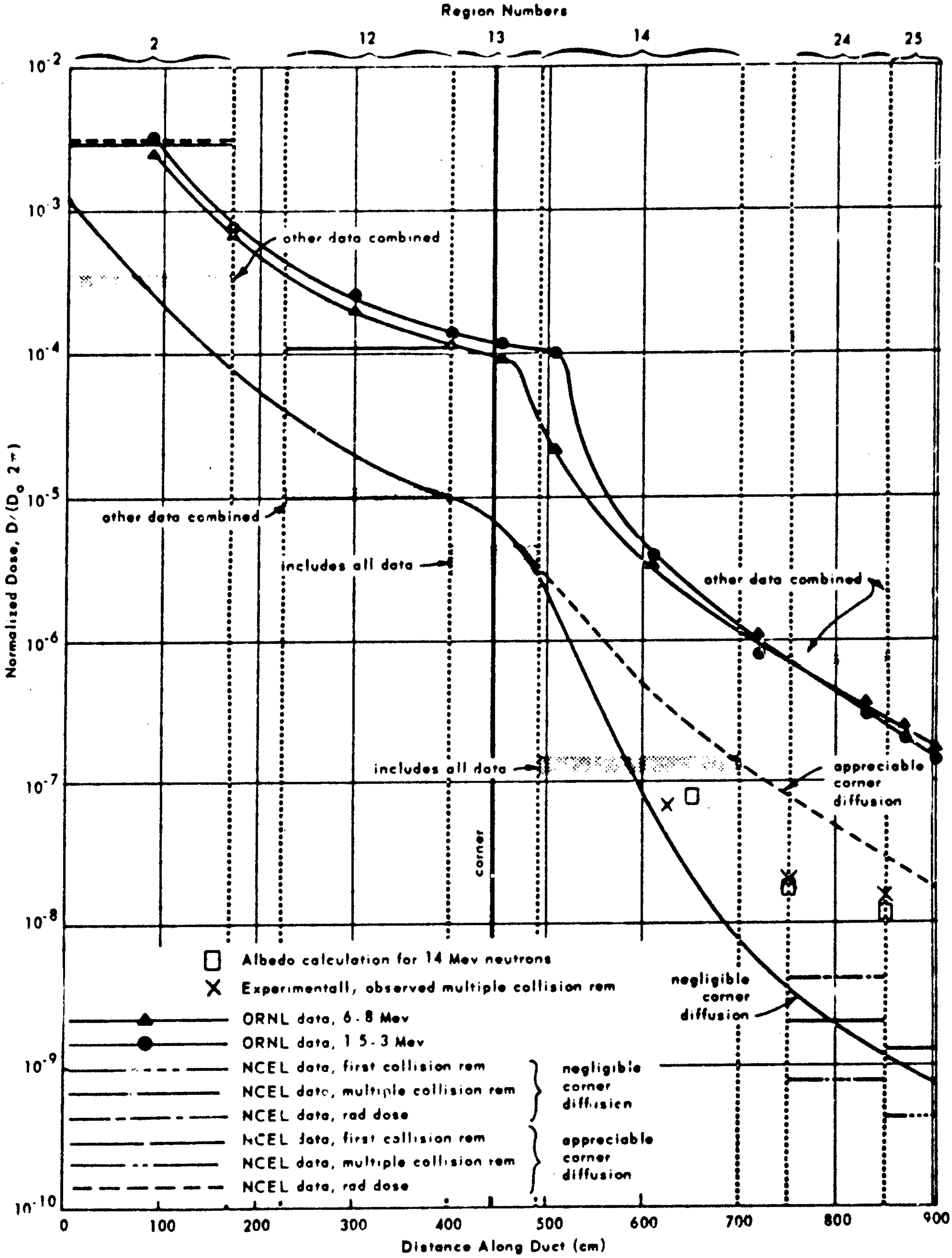


Figure 8. 3 x 3-foot duct, normalized neutron dose.

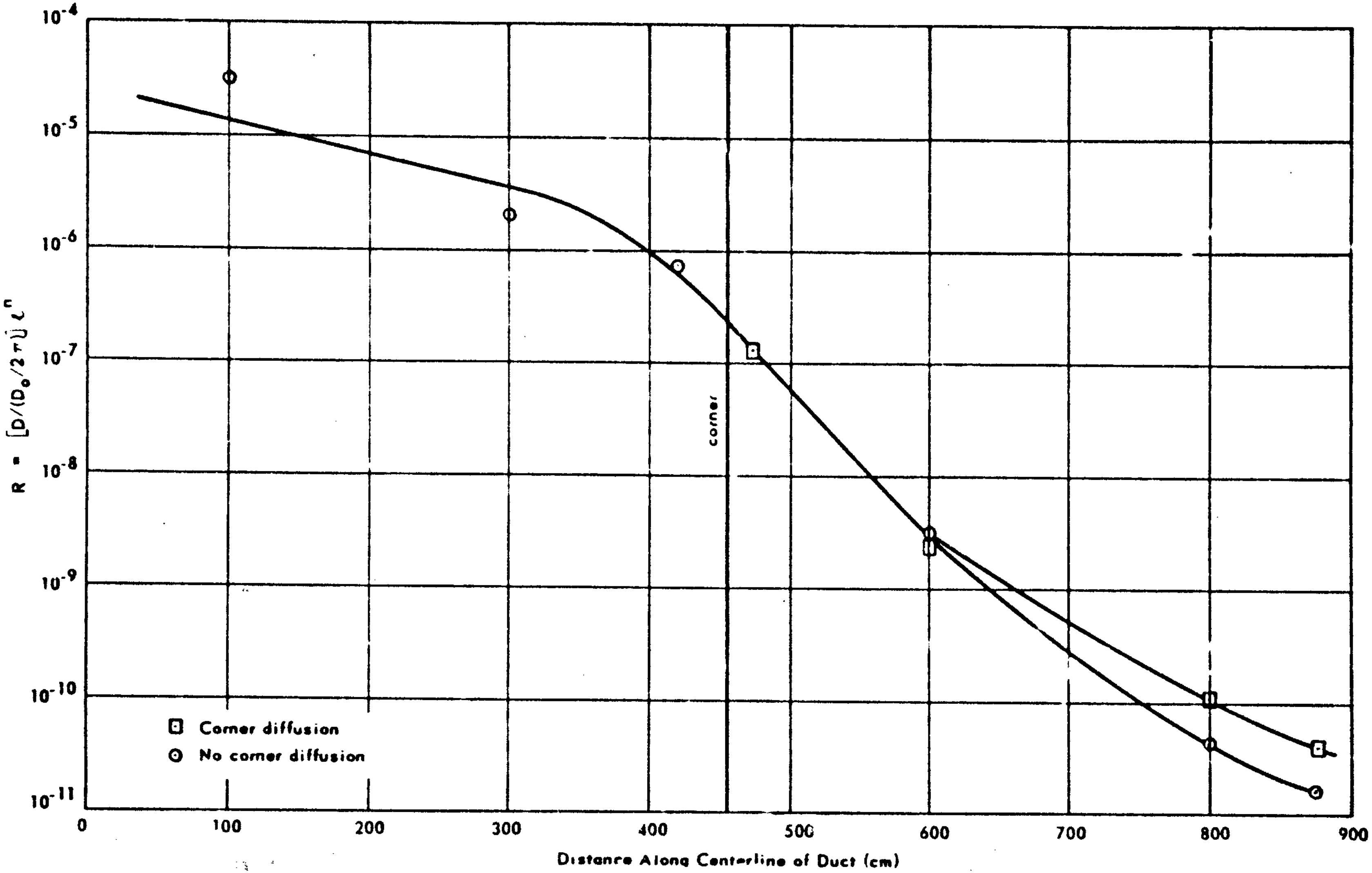


Figure 9. 3 x 3-foot duct, dose versus distance.

CONCLUSION AND RECOMMENDATIONS

The Monte Carlo calculations of neutron streaming through model ducted entranceways, performed utilizing the ADONIS code, and the Monte Carlo/Albedo calculations utilizing the ORNL code are in good agreement. Protection factors were found to be proportional to the duct cross-sectional area. It was found that albedo calculations of dose must be based upon a much greater corner penetration than previously assumed. This could decrease previously reported neutron protection factors by approximately a factor of 10. It remains, however, for these conclusions to be verified by carefully controlled experiments. By performing analytical calculations, as described, protection factors of structures may be readily determined with a fraction of the effort required by experimental methods. It is, however, necessary that all analytical techniques be verified by careful experiments. Once verified, the techniques may be freely applied in general extensions to the experiments.

It is recommended that the physics of neutron penetration between the first and second legs by methods other than streaming through the duct be more intensively investigated in order to establish the validity of albedo representations. It is also recommended that the ADONIS and ORNL codes be accepted as preferred analytical techniques for determining neutron streaming through ducted entranceways. The ADONIS code is applicable to most problems. The ORNL code, while requiring less running time, is applicable only to the case of a duct through a dense, infinitely bounded media, and thus it has limited practical applications.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Drs. R. L. Maerker and C. E. Clifford of ORNL for their discussion and assistance. Dr. Maerker was so kind as to calculate neutron dose in the 3-foot and 11-inch ducts, making these results available for comparison. They would also like to thank Mr. Y. T. Song, NCEL Physicist, who provided the results of his albedo calculations, Mr. J. Grant, NCEL Physicist, who reduced and analyzed the data reported herein, and Mr. F. S. Moore, formerly of this Laboratory, who originally suggested the idea of writing a computer program to calculate ADONIS input geometry. Fortunately, before this idea could be implemented, the program EASYGEOM was available and both Mr. K. Penny and Mrs. Betty Maskewitz, Radiation Shielding Information Center, ORNL, are to be thanked for making this program available to the authors. It is understood that EASYGEOM was originally programmed by Los Alamos Scientific Laboratory. Mr. Penny and Mrs. Maskewitz both provided invaluable and unlimited assistance and instructed the authors in the use of the ADONIS code. Mr. B. Eisenman of United Nuclear Corporation is also to be thanked for providing to NCEL the ADONIS code. The authors would also like to thank Mr. W. L. Wilcoxson, and the staff of the

NCEL Computer Laboratory, and the Point Mugu Computer Laboratory for their helpful assistance and cooperation in making the program runs described in the report. The latter are to be especially thanked since ADONIS requires running under FORTRAN II, version 2, necessitating a change in the machine room practice at Point Mugu.

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Table I. Listing of Source Deck for UNIGEOM With Subroutines

```
C     UNIFIED GEOMETRY FOR DUCTED SHIELDS
      DIMENSION  X(6,100),  KN(6,100),  IRX(6,100)
      DIMENSION IMX(116,25),  V(116,10),  H(116,10),  INX(116,10,10)
      DIMENSION NR(3),  NL(3),XR(3),XL(3)
      DIMENSION KIR(50),  VV(50),  HH(50)
      DIMENSION NH(116),NV(116)
      DIMENSION IPJ(30)
      COMMON X,IRX,H,V,INX,IERR
      COMMON IMAX,JMAX,IHMAX,IVMAX
      COMMON XL1,XL2,XL3,W1,W2,W3,TS11,TS12,TS21,TS22,TS31,TS32,TT,D1,
     1D2,D3,DA,DB,DC,DA1,DA2,DA3,TA,TB,TC,TD,HKH,H1,H2,XX
 7999 DO 9000 J=1,10
      DO 9000 I=1,116
      H(I,J)=0.
 9000 V(I,J)=0.
      READ INPUT TAPE 5,51,IMAX,IOP
   51 FORMAT(5I10)
      DO 300 I=1,6
      DO 300 J=1,80
  300 X(I,J)=0.
      READ INPUT TAPE 5,52,(XL1,XL2,XL3,W1,W2,W3)
      READ INPUT TAPE 5,52,(TS11,TS12,TS21,TS22,TS31,TS32)
      READ INPUT TAPE 5,52,(TT,D1,D2,D3,DA,DB)
      READ INPUT TAPE 5,52,(DC,DA1,DA2,DA3,TA,TB)
      READ INPUT TAPE 5,52,TC,TD,HKH,H1,H2,XX
 8001 GO TO (1000,1001,1002),IOP
 1000 CALL L2
      GO TO 5010
 1001 CALL L3Z
      GO TO 5010
 1002 CALL L3NCP
   52 FORMAT(6F10.5)
 5010 IF(IMAX-80) 60,60,61
 60   IFLAG=0
```

```
      KEEP=0
      JFLAG=0
      J=1
      IHMAX=0
      IVMAX=0
      MP=3
      MPP=1
      DO 3 I=1,100
      DO 3 J=1,6
      KN(J,I)=0
    3 IRX(J,I)=0
      IERR=0
      IDEL=-1
      DO 1 N=1,IMAX
      DO 1 M=1,6
      IDEL=-IDEL
      IF(IDEL)44,45,47
   47 MP=MP+2
      MPP=MPP+2
      IF(MP-6) 41,42,43
   43 MP=1
   41 IF(MPP-6)44,45,46
   46 MPP=1
   44 CONTINUE
      KNT= KN(M,N)
      K = 0
      IJ = N+1
      MMP=M+IDEL
      IF ( N- IMAX ) 10,11,12
   10                 DO 13 I= IJ,IMAX
      IF( X(M,N)- X(MMP    ,I) ) 13,14,13
   14 IF( X(MP,N) - X(MP,I) ) 15,16,17
   15 IF( X(MP+1,N) - X(MP,I)) 13,13,16
   17 IF( X(MP,N) - X(MP+1,I)) 16,13,13
   16 IF( X(MPP,N) - X(MPP,I)) 18,19,20
   18 IF( X(MPP+1,N) - X(MPP,I))13,13,19
   20 IF( X(MPP,N) - X(MPP+1,I))19,13,13
```

```
   19 K=K+1
      KIR(K) = I
      KN(MMP    ,I) = KN(MMP    ,I) + 1
      IF( KN(MMP    ,I) - 2) 21,22,23
   21 IRX(MMP    ,I) = N
      GO TO 13
   22 IF(KEEP) 451,452,453
  453 JPIM=J
      J=IPJ(KEEP)
  452 IMX(J,1)=IRX(MMP,I)
      IMX(J,2) = N
      IRX(MMP    ,I) = -J
      IF(KEEP) 451,454,455
  454 J=J+1
      GO TO 13
  455 J=JPIM
      KEEP=KEEP-1
      GO TO 13
   23 IF( IRX(MMP    ,I))24,25,26
   24 L= - IRX(MMP    ,I)
      LP = KN(MMP    ,I)
      IMX(L,LP) = N
   13 CONTINUE
   11 IF(KNT - 1) 101,102,103
  102 IF(K - 1)    1,104,104
  104 K - K+1
      KIR(K) = IRX(M,N)
      GO TO 107
  101 IF(K - 1) 106,108,107
  108 IRX(M,N) = KIR(K)
      GO TO    1
  107 IH=1
      IV=1
      HH(IH) = X(MP,N)
      VV(IV) = X(MPP,N)
      DO 121 IC = 1,K
      ICM = KIR(IC)
```

```
      IT = IH
      IM = 0
      HH(IT+1)=X(MP+1,ICM)
  112 IF (HH(IH+1)- HH(IT))109,110,111
  109 IM = IM+1
      IF (IT - 1) 113, 113, 115
  115 IT = IT-1
      GO TO 112
  111 IH=IH+1
      IF( IM ) 116,110,117
  117 IT= IT+1
      TEMP = HH(IT)
      HH(IT)= HH(IH)
      HH(IH)= TEMP
      IM = IM-1
      IF(IM) 118,110,117
  110 IT = IV
      IM = 0
      VV(IV+1) = X(MPP+1,ICM)
  124 IF(VV(IV+1) - VV(IT)) 120,121,122
  120 IM=IM+1
      IF(IT-1) 119,119,123
  123 IT= IT -1
      GO TO 124
  122 IV = IV+1
      IF( IM ) 125,121,127
  127 IT = IT +1
      TEMP = VV(IT)
      VV(IT) = VV(IV)
      VV(IV)= TEMP
      IM=IM-1
      IF(IM) 128,121,127
  121 CONTINUE
      IF(X(MP+1,N)-HH(IH))180,130,131
180   IH=IH-1
183   IF(X(MP+1,N)-HH(IH))180,182,181
182   IF(IH-1)184,184,130
```

```
181   IF(IH)189,189,188
188   IH=IH+1
      HH(IH)=X(MP+1,N)
 130  IF(X(MPP+1,N)-VV(IV))185,132,133
185   IV=IV-1
      IF(X(MPP+1,N)-VV(IV))185,186,187
 186  IF(IV-1)190,190,132
 187  IF(IV)191,191,192
 192  IV=IV+1
      VV(IV)=X(MPP+1,N)
 132  IT= IH-1
      IF(JFLAG) 166,456,457
 456  IF(KEEP) 166,457,458
 458  JPIM=J
      J=IPJ(KEEP)
      JFLAG=1
      KEEP=KEEP-1
 457  NH(J)=IT
      ITV = IV-1
      NV(J) = ITV
 134  H(J,IT) = HH(IT+1)
      IF(IT-1) 135,136,137
 137  IT=IT-1
      GO TO 134
 136  V(J,ITV) = VV(ITV+1)
      IF(ITV-1) 138,139,140
 140  ITV= ITV-1
      GO TO 136
 139  DO 141 IK=1,K
      ICM =KIR(IK)
      MH = 1
 146  IF(X(MP,ICM) - HH(MH)) 142,143,144
 142  IF(MH - 1) 145,143,145
 144  MH = MH+1
      IF(MH - IH) 146,147,147
 143  LH=MH
 151  IF(X(MP+1,ICM)- HH(LH+1)) 148,149,150
```

```
 150 LH=LH+1
     IF(LH-IH) 151,149,152
 148 IF(LH+1-IH) 153,149,153
 149 MV = 1
 158 IF( X(MPP,ICM) - VV(MV)) 154,155,156
 154 IF(MV - 1) 157,155,157
 156 MV=MV+1
     IF(MV - IV) 158,159,159
 155 LV=MV
 162 IF(X(MPP+1,ICM)-VV(LV+1))160,161,163
163  LV=LV+1
     IF(LV-IV)162,161,199
 160 LV =LV+1
     IF (LV - IV) 162,164,164
 161 DO 165 KV = MV, LV
     DO 165 KH = MH, LH
 165 INX(J, KH, KV) = ICM
 141 CONTINUE
176  IRX(M,N)=-J
     IF(JFLAG) 166,167,168
 167 J=J+1
     GO TO 169
 168 J=JPIM
     JFLAG=0
 169 IF( IHMAX - IH-1) 170,171,171
 170 IHMAX = IH-1
     IF(IHMAX - 10) 171,171,172
 171 IF(IVMAX-IV-1)173,471,471
 173 IVMAX = IV-1
     IF(IVMAX-10) 471,471,175
 471 IJ=-IRX(M,N)
     KTH=NH(IJ)
     KTV=NV(IJ)
     DO 486 KV=1,KTV
     DO 486 KH=1,KTH
     ICM=INX(IJ,KH,KV)
     IF(IRX(M,ICM))486,486,473
```

```
486 CONTINUE
    GO TO 1
473 IOPP=IRX(M,ICM)
    MID=M+IDEL
    IF(IOPP-N) 474,472,  1
474 IF(IRX(MID    ,IOPP)) 475,472,  1
475 IJP=-IRX(MID    ,IOPP)
    IF(NH(IJ)-NH(IJP))  1,476,  1
476 IF(NV(IJ)-NV(IJP))   1,477,  1
477 DO 478 IT=1,KTH
    IF(H(IJP,IT)-H(IJ,IT))    1,478,  1
478 CONTINUE
    DO 479 IT=1,KTV
    IF(V(IJP,IT)-V(IJ,IT))    1,479,  1
479 CONTINUE
    DO 480 ITV=1,KTV
    DO 480 IT=1,KTH
    IF(INX(IJ,IT,ITV)-INX(IJP,IT,ITV))    1,480,  1
480 CONTINUE
    IF(J-1-IJ) 472,481,482
482 IF(J-1-IJP) 472,483,484
484 KEEP=KEEP+1
    IPJ(KEEP)=IJ
    IF(KEEP-30) 487,472,472
481 IRX(M,N)=-IJP
    GO TO 485
483 IRX(MID    ,IOPP)=-IJ
485 J=J-1
    GO TO    1
487 IRX(M,N)=-IJP
    GO TO    1
472 IERR=472
    GO TO 406
451 IERR=451
    CG TO 406
106 IF(IFLAG - 1) 206,207,204
206 IFLAG = 1
```

```
      ICNTR = 1
      IDR = IDEL
  203 NR(ICNTR) = M
      XR(ICNTR)= X(M,N)
      GO TO 202
  207 IF(IDR -IDEL) 208,201,208
  208 IFLAG = 2
      ICNTL = 1
  205 NL(ICNTL)=M
      XL(ICNTL)= X(M,N)
  202 IRX(M,N) = N
      GO TO    1
  201 INT = 1
  215 IF( M - NR(INT))209,210,209
  210 IF(XR(INT) - X(M,N)) 211,202,211
  209 IF(INT -ICNTR) 212,213,214
  212 INT = INT+1
      GO TO 215
  213 ICNTR =ICNTR+1
      IF(ICNTR -3) 203, 203, 216
  204 IF (IDR -IDEL) 217,201,217
  217 INT = 1
  224 IF( M - NL(INT))218,219,218
  219 IF(XL(INT) - X(M,N)) 220,202,220
  218 IF(INT - ICNTL) 221,222,223
  221 INT = INT+1
      GO TO 224
  222 ICNTL = ICNTL + 1
      IF( ICNTL-3) 205,205,225
  103 IF(K)  303, 304,304
  304 JPIM  = J
      J= -IRX(M,N)
      JFLAG = 1
  305 DO 306 IT =1,KNT
      K = K+1
  306 KIR(K) = IMX(J,IT)
      GO TO 107
```

```
   12 IERR= 12
      GO TO 406
   25 IERR= 25
      GO TO 406
   26 IERR= 26
      GO TO 406
  113 IERR =113
      ASSIGN 176 TO KERRP
      GO TO 800
  116 IERR= 116
      GO TO 406
  118 IERR= 118
      GO TO 406
  119 IERR= 119
      ASSIGN 176 TO KERRP
      GO TO 800
  125 IERR= 125
      GO TO 406
  128 IERR= 128
      GO TO 406
  131 IERR= 131
      ASSIGN 799 TO KERRP
      GO TO 800
  133 IERR= 133
      ASSIGN 799 TO KERRP
      GO TO 800
  135 IERR= 135
      GO TO 406
  138 IERR= 138
      GO TO 406
  145 IERR= 145
      GO TO 406
  147 IERR= 147
      GO TO 406
  152 IERR= 152
      GO TO 406
  153 IERR= 153
```

```
      GO TO 406
  157 IERR= 157
      GO TO 406
  159 IERR= 159
      GO TO 406
  164 IERR= 164
      GO TO 406
  166 IERR= 166
      GO TO 406
  172 IERR= 172
      GO TO 406
  175 IERR= 175
      GO TO 406
  211 IERR= 211
      GO TO 406
  214 IERR= 214
      GO TO 406
  216 IERR= 216
      GO TO 406
  220 IERR= 220
      ASSIGN 690 TO KERRP
      GO TO 410
  223 IERR= 223
      GO TO 406
  225 IERR= 225
      GO TO 406
  303 IERR= 303
      GO TO 406
 199  IERR=199
      GO TO 406
 500  IERR=500
      GO TO 406
  1   CONTINUE
      JMAX=J-1
      IF(IERR)500,501,502
  501 EPSE=1.0E+09
      EPSEE=1.0E+04
```

```
      DO 2 I=1,6
      DO 2 J=1,100
      IF(ABSF(X(I,J))-EPSE)2,8,2
    8 X(I,J)=X(I,J)/EPSEE
    2 CONTINUE
      DO 4 I=1,116
      DO 4 J=1,10
      IF(ABSF(H(I,J))-EPSE)4,5,4
    5 H(I,J)=H(I,J)/EPSEE
    4 CONTINUE
      DO 6 I=1,116
      DO 6 J=1,10
      IF(ABSF(V(I,J))-EPSE)6,7,6
    7 V(I,J)=V(I,J)/EPSEE
    6 CONTINUE
      CALL TESTG
      IF(IERR) 6001,6001,502
 6001 EPSEE=1.0E+05
      EPSE=1.0E+04
      DO 9222 I=1,6
      DO 9222 J=1,100
      IF(ABSF(X(I,J))-EPSEE)9222,9223,9222
 9223 X(I,J)=X(I,J)*EPSE
 9222 CONTINUE
      WRITE OUTPUT TAPE 6,550,JMAX,IHMAX,IVMAX
      WRITE OUTPUT TAPE 6,551,((X(M,N),M=1,6), N,N=1,IMAX)
      WRITE OUTPUT TAPE 13,5551,((X(M,N),M=1,6), N,N=1,IMAX)
      WRITE OUTPUT TAPE 6,552,  ((IRX(M,N),M=1,6),N,N=1,IMAX)
      WRITE OUTPUT TAPE 13,5552,((IRX(M,N),M=1,5),N,N=1,IMAX)
B     FBLANK=606060606060
B     FPLUS=202020202020
B     FMINUS=404040404040
      WRITE OUTPUT TAPE 6,553
      I=1
 8030 DO 8050 N=1,JMAX
      NM=NH(N)
      WRITE OUTPUT TAPE 6,557,N,(H(N,M),M=1,NM)
```

```
      DO 8040 M=1,NM
      ZZ=ABSF(H(N,M))
9224  IF(ZZ-999.99)8041,8041,8042
8041  IF(H(N,M))8043,8040,8046
8043  H(N,M)=H(N,M)-.005
      GO TO 8040
8046  H(N,M)=H(N,M)+.005
8040  CONTINUE
      WRITE OUTPUT TAPE 13,5557,(H(N,M),M=1,NM)
      GO TO 8050
8042  IF(ZZ-100000.)8051,8052,8051
8052  GO TO(8002,8003,8004,8005,8006,8007,8008,8009,8010,8011),M
8051  WRITE OUTPUT TAPE 13,5558,N,M,H(N,M)
8050  CONTINUE
      IF(I-1)8014,8013,8014
8013  DO 8012 N=1,JMAX
      NM=NV(N)
      DO 8015 M=1,NM
8015  H(N,M)=V(N,M)
      ZZ=NH(N)
      NH(N)=NV(N)
8012  NV(N)=ZZ
      I=20
      GO TO 8030
8014  CONTINUE
      DO 505 J=1,JMAX
      NHP=NV(J)
      NVP=NH(J)
      WRITE OUTPUT TAPE 6,555, NHP,NVP,((INX(J,M,N),M=1,NHP),N=1,NVP)
505   WRITE OUTPUT TAPE 13,5559,NHP,NVP,((INX(J,M,N),M=1,NHP),N=1,NVP)
550   FORMAT(97H1NUMBER OF COMPLEX SURFACES   MAX NUMBER OF HORIZONTAL
     1-- VERTICAL SURFACES PER COMPLEX SURFACE / I18,I36,I13)
551   FORMAT(21X21H BOUNDING PLANE INPUT //(6(1PE14.5),5HBPO  I3))
5551  FORMAT(6E12.5,5HBPO  I3)
552   FORMAT(21X 22H ADJACENT REGION INPUT //(6I10,12X 5HIRX  I3))
5552  FORMAT(6I10,12X,5HIRX  I3)
553   FORMAT(21X 18H  HORIZONTAL INPUT  //)
```

```
554   FORMAT(21X 16H  VERTICAL INPUT  //)
 555  FORMAT(24I3)
5559  FORMAT(24I3)
5555   FORMAT(21X 22H  COMPLEX REGION INPUT    //)
556   FORMAT(10E7.1)
5557  FORMAT(10F7.2)
 557  FORMAT (I4,10(1PE12.5))
5558  FORMAT(2I10,E12.5,18HEXCEEDS 'F' FORMAT)
      GO TO 799
42    IERR=42
      GO TO 406
45    IERR=45
      GO TO 406
 184  IERR=184
      ASSIGN 176 TO KERRP
      GO TO 800
 189  IERR=189
      ASSIGN 176 TO KERRP
      GO TO 800
190   IERR=190
      ASSIGN 176 TO KERRP
      GO TO 800
 191  IERR=191
      ASSIGN 176 TO KERRP
      GO TO 800
61    IERR=61
      GO TO 406
 502  STOP 322
406   ASSIGN 799 TO KERRP
410   WRITE OUTPUT TAPE 6,650,IERR,M,N,J,K,X(M,N),(KIR(MNO),MNO=1,K)
650   FORMAT(17H1 ERROR NUMBER =  I5/20H  M  N  J  K  X(M,N) / 4I3,
     1E15.5,//21X6HKIR(K) // 20I5)
      WRITE OUTPUT TAPE 6,651,((IRX(MNO,NMO),MNO=1,6),(KN(MNP,NMO),
     1MNP=1,6),NMO=1,IMAX)
      GO TO KERRP,(176,690,799)
690   WRITE OUTPUT TAPE 6,652,X(M,N),XL(ICNTL)
      X(M,N)=XL(ICNTL)
```

```
651   FORMAT(20X8HIRX(M,N)21X7HKN(M,N)/(10X6I3,10X6I3))
652   FORMAT(14X6HX(M,N) 5X1H=  11X9HXL(ICNTL)/E20.7,6XE20.7)
      GO TO 202
800   WRITE OUTPUT TAPE 6,850,IM,IH,IC,ICM,J,IV,(HH(MNO),MNO=1,IH)
      WRITE OUTPUT TAPE 6,52,(VV(NMO),NMO=1,IV)
      WRITE OUTPUT TAPE 6,52,HH(IH+1),HH(IT),VV(IV+1),VV(IT)
850   FORMAT(1H0,6I5//(6E15.5))
      GO TO 410
799   CONTINUE
 601  GO TO 7999
8002  WRITE OUTPUT TAPE 13,8602,(H(N,M),M=1,NM)
      GO TO 8050
8003  WRITE OUTPUT TAPE 13,8603,(H(N,M),M=1,NM)
      GO TO 8050
8004  WRITE OUTPUT TAPE 13,8604,(H(N,M),M=1,NM)
      GO TO 8050
8005  WRITE OUTPUT TAPE 13,8605,(H(N,M),M=1,NM)
      GO TO 8050
8006  WRITE OUTPUT TAPE 13,8606,(H(N,M),M=1,NM)
      GO TO 8050
8007  WRITE OUTPUT TAPE 13,8607,(H(N,M),M=1,NM)
      GO TO 8050
8008  WRITE OUTPUT TAPE 13,8608,(H(N,M),M=1,NM)
      GO TO 8050
8009  WRITE OUTPUT TAPE 13,8609,(H(N,M),M=1,NM)
      GO TO 8050
8010  WRITE OUTPUT TAPE 13,8610,(H(N,M),M=1,NM)
      GO TO 8050
8011  WRITE OUTPUT TAPE 13,8611,(H(N,M),M=1,NM)
      GO TO 8050
9111  FORMAT(9HERROR 322)
8602  FORMAT(F7.0,9F7.2)
8603  FORMAT(F7.2,F7.0,8F7.2)
8604  FORMAT(2F7.2,F7.0,7F7.2)
8605  FORMAT(3F7.2,F7.0,6F7.2)
8606  FORMAT(4F7.2,F7.0,5F7.2)
8607  FORMAT(5F7.2,F7.0,4F7.2)
```

```
8608 FORMAT(6F7.2,F7.0,3F7.2)
8609 FORMAT(7F7.2,F7.0,2F7.2)
8610 FORMAT(8F7.2,F7.0,F7.2)
8611 FORMAT(9F7.2,F7.0)
     END


     SUBROUTINE TESTG
     COMMON A,IRX,H,V,MX,IERR
     COMMON IRMAX,MPMAX,LMAX,MMAX
     COMMON XO,W,BADMAL,IRPRIM,SM,KM,IM,IR,XSI
     COMMON NFIRST,NLAST,IRSTRT,IETAG,ICDMPT,JMAX,JSIGM,ECUT
     COMMON PINF,IRT,MC,MR,EPSI,ISWM
     DIMENSION A(6,100),H(116,10),V(116,10),MX(116,10,10),IRX(6,100)
     DIMENSION XO(3),W(3),MC(80),MR(80),X1(3),X2(3),S(100),K(100)
     DIMENSION I(100),X(3,100),IRP(100)
   1 FORMAT(5H IRS=I2,6H   IRF=I2)
   2 FORMAT(4H X1=1PE14.7,1P2E17.7)
   3 FORMAT(4H X2=1PE14.7,1P2E17.7)
   4 FORMAT(3H W=1PE14.7,1P2E17.7)
   5 FORMAT(79H  N        X(1,N)            X(2,N)             X(3,N'
    X    S(N)        K  I   IRP)
   6 FORMAT(I4,1P4E16.7,2I3,I5)
   7 FORMAT(5H0ISW=I3)
   9 FORMAT  (E14.7,5I3)
  10 FORMAT (6E12.7)
  11 FORMAT(10E7.4)
  12 FORMAT (24I3)
  13 FORMAT (6I10)
     EPSI=.001
     ISWM=3
  40 ISW=1
```

```
 43 IRS=1
 45 IRF=1
    IF (IRS-(IRMAX+1)) 42, 82, 81
 82 IF(ISW-ISWM) 84,86,80
 84 PRINT 7, ISW
    ISW=ISW+1
    GO TO 43
 42 IF(IRF-(IRMAX+1)) 46,44,85
 44 IRS=IRS+1
    GO TO 45
 86 PRINT 7, ISW
    RETURN
 61 BADMAL=SQRTF((X2(1)-X1(1))**2+(X2(2)-X1(2))**2+(X2(3)-X1(3))**2)
    DO 47 I=1,3
 47 W(I)=(X2(I)-X1(I))/BADMAL
    IR=IRS
    DO 62I=1,3
 62 XO(I)=X1(I)
 24 CALL G1
 49 S(J)=SM
    K(J)=KM
    I(J)=IM
 48 IF (SM-BADMAL) 20, 21, 21
 20 CALL G2
    IF ( IRPRIM )  30,30,101
101 CONTINUE
    DO 52 I=1,3
 52 X(I,J)=XO(I)
    IRP (J)=IRPRIM
    J=J+1
    IF(J-100)51,30,30
 51 BADMAL = BADMAL -SM
    IR=IRPRIM
    IF ( IRPRIM-80 ) 24,24,30
 80 RETURN
 81 RETURN
 85 RETURN
```

```
 21 SM=BADMAL
    DO 26 I=1,3
 26 XO(I)=XO(I)+W(I)*SM
    DO 29 I=1,3
 27 IF(ABSF(1.-X2(I)/XO(I))-EPSI)29,29,30
 29 CONTINUE
 31 IRF = IRF+1
    GO TO 42
 30 WRITE OUTPUT TAPE 6,1, IRS,IRF
    WRITE OUTPUT TAPE 6,2,(X1(I),I=1,3)
    WRITE OUTPUT TAPE 6,3,(X2(I),I=1,3)
    WRITE OUTPUT TAPE 6,4,(W(I),I=1,3)
    WRITE OUTPUT TAPE 6,5
    WRITE OUTPUT TAPE 6,6,(N,(X(I,N),I=1,3),S(N),K(N),I(N),
   X  IRP (N), N=1,J)
    IF(J-100)100,201,201
201 IERR=10
100 GO TO 31
 46 DO 60 I=1,3
    CALL RANDOM(XSI,1)
    X1(I)=A(2*I-1,IRS)+XSI*(A(2*I,IRS)-A(2*I-1,IRS))
    CALL RANDOM(XSI,1)
 60 X2(I)=A(2*I-1,IRF)+XSI*(A(2*I,IRF)-A(2*I-1,IRF))
    J=1
    GO TO 61
    END
    SUBROUTINE G2
    COMMON A,IRX,H,V,MX,IERR
    COMMON IRMAX,MPMAX,LMAX,MMAX
    COMMON XO,W,BADMAL,IRPRIM,SM,KM,IM,IR,XSI
    COMMON NFIRST,NLAST,IRSTRT,IETAG,ICDMPT,JMAX,JSIGM,ECUT
    COMMON PINF,IRT,MC,MR,EPSI,ISWM
    DIMENSION A(6,100),H(116,10),V(116,10),MX(116,10,10),IRX(6,100)
    DIMENSION XO(3),W(3),MC(80),MR(80),X1(3),X2(3),S(100),K(100)
    DIMENSION I(100),X(3,100),IRP(100)
    DO 1 I=1,3
    IF(I-IM) 2,1,2
```

```
2 XO(I)=XO(I)+W(I)*SM
1 CONTINUE
  XO(IM)=A(KM,IR)
  IF(IRX(KM,IR)) 4,15,3
3 IRPRIM = IRX(KM,IR)
  GO TO 14
4 IF(IM-2) 5,6,7
5 XH=XO(3)
  XV=XO(2)
  GO TO 8
6 XH = XO(1)
  XV = XO(3)
  GO TO 8
7 XH = XO(2)
  XV = XO(1)
8 L=1
  M = 1
  MPRIM = XABSF(IRX(KM,IR))
11 IF(XH-H(MPRIM,L))10,10,9
 9 L = L+1
  GO TO 11
10 IF(XV-V(MPRIM,M)) 12, 12, 13
13 M = M+1
  GO TO 10
12 IRPRIM = MX(MPRIM,L,M)
14 RETURN
15 STOP 15
  END
  SUBROUTINE G1
  COMMON A,IRX,H,V,MX,IERR
  COMMON IRMAX,MPMAX,LMAX,MMAX
  COMMON XO,W,BADMAL,IRPRIM,SM,KM,IM,IR,XSI
  COMMON NFIRST,NLAST,IRSTRT,IETAG,ICDMPT,JMAX,JSIGM,ECUT
  COMMON PINF,IRT,MC,MR,EPSI,ISWM
  DIMENSION A(6,100),H(116,10),V(116,10),MX(116,10,10),IRX(6,100)
  DIMENSION XO(3),W(3),MC(80),MR(80),X1(3),X2(3),S(100),K(100)
  DIMENSION I(100),X(3,100),IRP(100)
```

```
      IF DIVIDE CHECK 1,1
    1 SM=1.E9
      K=1
      DO 37 I=1,3
      IF(A(K,IR)-XO(I)) 32,33,32
   32 S=(A(K,IR)-XO(I))/W(I)
      IF DIVIDE CHECK2,3
    2 KDEL=2
      GO TO 37
    3 IF(S)33,38,34
   34 KDEL =2
      GO TO 35
   33 K=K+1
      KDEL =1
      S=(A(K,IR)-XO(I))/W(I)
      IF DIVIDE CHECK 37,35
   35 IF(S-SM) 36,36,37
   36 SM=S
      KM=K
      IM=I
   37 K=K+KDEL
      RETURN
   38 STOP 46
      END
```

```
      SUBROUTINE L2
      DIMENSION X(6,100),IRX(6,100),H(116,10),V(116,10),INX(116,10,10)
      COMMON X,IRX,H,V,INX,IERF
      COMMON IMAX,JMAX,IHMAX,IVMAX
      COMMON XL1,XL2,XL3,W1,W2,W3,TS11,TS12,TS21,TS22,TS31,TS32,TT,D1,
     1D2,D3,DA,DB,DC,DA1,DA2,DA3,TA,TB,TC,TD,HH,H1,H2,XX
```

```
      XINF=1.0E+09
2000  A=W1-TS11-TS12
      IF(A)2001,2001,2002
2001  WRITE OUTPUT TAPE 6,3001
2002  CONTINUE
2003  B=W2-TS21-TS22
      IF(B)2004,2004,2005
2004  WRITE OUTPUT TAPE 6,3002
2005  CONTINUE
2006  C=XL1-D1+DA
      IF(C)2007,2007,2008
2007  WRITE OUTPUT TAPE 6,3003
2008  CONTINUE
2009  E=XL2-D2-DA
      IF(E)2010,2010,2011
2010  WRITE OUTPUT TAPE 6,3004
2011  CONTINUE
2012  F=HH-H1-H2
      IF(F)2013,2013,2014
2013  WRITE OUTPUT TAPE 6,3005
2014  CONTINUE
2015  G=HH-H1-H2-DC
      IF(G)2016,2016,2017
2016  WRITE OUTPUT TAPE 6,3006
2017  CONTINUE
2018  P=W1-TS11-TS12-DB
      IF(P)2019,2019,2020
2019  WRITE OUTPUT TAPE 6,3007
2020  CONTINUE
2021  Q=W2-TS21-TS22-DB
      IF(Q)2022,2022,2023
2022  WRITE OUTPUT TAPE 6,3007
2023  CONTINUE
      X(4,24)=XL2-TT
      X(3,25)=XL2-TT
      X(4,25)=XL2
      X(3,26)=0.
```

```
X(4,26)=W1
X(3,27)=W1-TS12
X(4,27)=W1
X(3,28)=0.
X(4,28)=W1
X(3,29)=0.
X(4,29)=TS11
X(3,30)=W1
X(3,31)=W1
X(3,32)=W1
X(3,33)=TS11
X(3,34)=W1
X(3,35)=-TA
X(3,36)=-TA
X(3,37)=-TA
X(4,30)=XL2
X(4,31)=XL2
X(4,32)=XL2
X(4,33)=XL2
X(4,34)=XL2
X(4,35)=XL2
X(4,36)=XL2
X(4,38)=XL2
X(4,39)=XL2
X(4,40)=XL2
X(4,37)=0.
X(3,38)=0.
X(3,39)=-TA
X(3,40)=-TA
X(3,41)=-TA
X(4,41)=XL2
X(3,42)=-TA
X(4,42)=XL2
X(3,43)=XL2
X(4,43)=XINF
X(5,1)=-XINF
X(6,1)=XINF
```

```
X(5,2)=-HH+H2
X(5,3)=-HH+H2
X(5,4)=-HH+H2
X(5,5)=-HH+H2
X(6,2)=-H1
X(1,1)=-XINF
X(2,1)=XINF
X(1,2)=XL1-D1
X(2,3)=X(1,2)
X(2,4)=X(1,2)
X(2,5)=X(1,2)
X(2,6)=X(1,2)
X(2,7)=X(1,2)
X(2,8)=X(1,2)
X(2,9)=X(1,2)
X(2,10)=X(1,2)
X(2,11)=X(1,2)
X(2,2)=XL1
X(2,26)=XL1
X(2,27)=XL1
X(2,28)=XL1
X(2,29)=XL1
X(2,34)=XL1
X(2,35)=XL1
X(2,36)=XL1
X(2,37)=XL1
X(2,40)=XL1
X(1,41)=XL1
X(1,3)=XL1-D1-DA
X(1,4)=X(1,3)
X(1,5)=X(1,3)
X(1,6)=X(1,3)
X(1,7)=X(1,3)
X(1,8)=X(1,3)
X(1,9)=X(1,3)
X(1,10)=X(1,3)
X(1,11)=X(1,3)
```

```
X(2,12)=X(1,3)
X(1,12)=W2-TS22
X(2,13)=X(1,12)
X(2,14)=X(1,12)
X(2,15)=X(1,12)
X(2,18)=X(1,12)
X(2,21)=X(1,12)
X(2,24)=X(1,12)
X(2,25)=X(1,12)
X(1,27)=X(1,12)
X(1,31)=X(1,12)
X(1,13)=TS21
X(1,14)=TS21
X(1,17)=TS21
X(1,20)=TS21
X(1,23)=TS21
X(1,24)=TS21
X(1,25)=TS21
X(2,33)=TS21
X(1,15)=TS21+(W2-TS21-TS22)/2.+0.5
X(2,16)=X(1,15)
X(1,18)=X(1,15)
X(2,19)=X(1,15)
X(1,21)=X(1,15)
X(2,22)=X(1,15)
X(1,16)=X(1,15)-1.
X(2,17)=X(1,16)
X(1,19)=X(1,16)
X(2,20)=X(1,16)
X(1,22)=X(1,16)
X(2,23)=X(1,16)
X(1,26)=0.
X(1,28)=0.
X(1,29)=0.
X(1,30)=0.
X(2,30)=W2
X(2,31)=W2
```

```
X(1,32)=0.
X(2,32)=W2
X(1,33)=0.
X(1,34)=W2
X(1,35)=-TB
X(1,36)=-TB
X(1,37)=-TB
X(1,38)=-TB
X(2,38)=0.
X(1,39)=-XINF
X(2,39)=XL1
X(1,40)=-XINF
X(2,41)=XINF
X(1,42)=-XINF
X(2,42)=-TB
X(1,43)=-XINF
X(2,43)=XINF
X(3,1)=-XINF
X(4,1)=-TA
X(3,2)=TS11
X(4,2)=W1-TS12
X(4,3)=X(4,2)
X(4,6)=X(4,2)
X(4,9)=X(4,2)
X(4,12)=X(4,2)
X(4,13)=X(4,2)
X(3,14)=X(4,2)
X(3,3)=TS11+(W1-TS11-TS12)/2.+0.5
X(4,4)=X(3,3)
X(3,6)=X(3,3)
X(4,7)=X(3,3)
X(3,9)=X(3,3)
X(4,10)=X(3,3)
X(3,4)=X(3,3)-1.
X(4,5)=X(3,4)
X(3,7)=X(3,4)
X(4,8)=X(3,4)
```

```
X(3,10)=X(3,4)
X(4,11)=X(3,4)
X(3,5)=TS11
X(3,8)=TS11
X(3,11)=TS11
X(3,12)=TS11
X(3,13)=TS11
X(4,14)=XL2-D2-DA
X(3,15)=X(4,14)
X(3,16)=X(4,14)
X(3,17)=X(4,14)
X(3,18)=X(4,14)
X(3,19)=X(4,14)
X(3,20)=X(4,14)
X(3,21)=X(4,14)
X(3,22)=X(4,14)
X(3,23)=X(4,14)
X(4,15)=XL2-D2
X(4,16)=X(4,15)
X(4,17)=X(4,15)
X(4,18)=X(4,15)
X(4,19)=X(4,15)
X(4,20)=X(4,15)
X(4,21)=X(4,15)
X(4,22)=X(4,15)
X(4,23)=X(4,15)
X(3,24)=X(4,15)
X(6,3)=-H1-(HH-H1-H2)/2.-0.5
X(6,4)=X(6,3)
X(6,5)=X(6,3)
X(5,6)=X(6,3)
X(5,7)=X(6,3)
X(5,8)=X(6,3)
X(6,6)=X(6,3)+1.
X(6,7)=X(6,6)
X(6,8)=X(6,6)
X(6,9)=-H1
```

```
X(6,10)=-H1
X(6,11)=-H1
X(6,12)=-H1
X(6,13)=-H1
X(6,14)=-H1
X(5,9)=X(6,6)
X(5,10)=X(6,6)
X.5,11)=X(6,6)
X(5,12)=-HH+H2
X(5,13)=X(5,12)
X(5,14)=X(5,12)
X(5,15)=X(5,12)
X(5,16)=X(5,12)
X(5,17)=X(5,12)
X(6,15)=X(6,3)
X(6,16)=X(6,3)
X(6,17)=X(6,3)
X(5,18)=X(6,3)
X(5,19)=X(6,3)
X(5,20)=X(6,3)
X(6,21)=-H1
X(6,22)=-H1
X(6,23)=-H1
X(6,18)=X(6,6)
X(6,19)=X(6,6)
X(6,20)=X(6,6)
X(5,21)=X(6,6)
X(5,22)=X(6,6)
X(5,23)=X(6,6)
X(5,24)=-HH+H2
X(5,25)=X(5,24)
X(5,27)=X(5,24)
X(6,28)=X(5,24)
X(5,29)=X(5,24)
X(5,31)=X(5,24)
X(6,32)=X(5,24)
X(5,33)=X(5,24)
```

```
      X(6,24)=-H1
      X(6,25)=-H1
      X(5,26)=-H1
      X(6,26)=0.
      X(6,27)=-H1
      X(5,28)=-HH
      X(6,29)=-H1
      X(5,30)=-H1
      X(6,30)=0.
      X(6,31)=-H1
      X(5,32)=-HH
      X(6,33)=-H1
      X(5,34)=-HH
      X(6,34)=0.
      X(5,35)=0.
      X(6,35)=TC
      X(5,36)=-HH-TD
      X(6,36)=-HH
      X(5,37)=-HH
      X(6,37)=0.
      X(5,38)=-HH
      X(6,38)=0.
      X(5,39)=TC
      X(6,39)=XINF
      X(5,40)=-XINF
      X(6,40)=-HH-TD
      X(5,41)=-XINF
      X(6,41)=XINF
      X(5,42)=-HH-TD
      X(6,42)=TC
      X(5,43)=-XINF
      X(6,43)=XINF
      RETURN
 3001 FORMAT(19HNEG THICKNESS LEG 1)
 3002 FORMAT(19HNEG THICKNESS LEG 2)
 3003 FORMAT(16HNEG LENGTH LEG 1)
 3004 FORMAT(16HNEG LENGTH LEG 2)
```

```
3005 FORMAT(10HNEG HEIGHT)
3006 FORMAT(19HNEG DETECTOR HEIGHT)
3007 FORMAT(18HNEG DETECTOR WIDTH)
     END
```

```
     SUBROUTINE L3Z
     DIMENSION X(6,100),IRX(6,100),H(116,10),V(116,10),INX(116,10,10)
     COMMON X,IRX,H,V,INX,IERR
     COMMON IMAX,JMAX,IHMAX,IVMAX
     COMMON XL1,XL2,XL3,W1,W2,W3,TS11,TS12,TS21,TS22,TS31,TS32,TT,D1,
    1D2,D3,DA,DB,DC,DA1,DA2,DA3,TA,TB,TC,TD,HH,H1,H2,XX
     XINF=1.E+09
2000 A=W1-TS11-TS12
     IF(A)2001,2001,2002
2001 WRITE OUTPUT TAPE 6,3001
2002 CONTINUE
2003 B=W3-TS31-TS32
     IF(B)2004,2004,2005
2004 WRITE OUTPUT TAPE 6,3002
2005 CONTINUE
2006 C=W2-TS31-TS32
     IF(C)2007,2007,2008
2007 WRITE OUTPUT TAPE 6,3003
2008 CONTINUE
2009 E=XL3-D1-DA1
     IF(E)2010,2010,2011
2010 WRITE OUTPUT TAPE 6,3004
2011 CONTINUE
2012 F=XL1-D2-DA2
     IF(F)2013,2013,2014
2013 WRITE OUTPUT TAPE 6,3005
```

```
2014 CONTINUE
2015 G=XL2-W1-W3
     IF(G)2016,2016,2017
2016 WRITE OUTPUT TAPE 6,3006
2017 CONTINUE
2018 P=HH-H1-H2
     IF(P)2019,2019,2020
2019 WRITE OUTPUT TAPE 6,3007
2020 CONTINUE
     X(1,3)=XL2-W1+TS12
     X(1,29)=X(1,3)
     X(1,32)=X(1,3)
     X(1,35)=X(1,3)
     X(2,4)=X(1,3)
     X(2,5)=X(1,3)
     X(1,8)=X(1,3)
     X(2,3)=XL2-TS11
     X(2,27)=X(2,3)
     X(2,30)=X(2,3)
     X(2,33)=X(2,3)
     X(1,2)=X(2,3)
     X(2,6)=X(2,3)
     X(2,8)=X(2,3)
     X(1,45)=TS32
     X(1,46)=TS32
     X(2,45)=W3-TS31
     X(2,36)=X(2,45)
     X(2,39)=X(2,45)
     X(2,42)=X(2,45)
     X(2,46)=X(2,45)
     X(1,5)=X(2,45)
     X(1,7)=X(2,45)
     X(1,47)=-XINF
     X(2,47)=XINF
     X(1,27)=XL2-TS11-(W1-TS11-TS12)/2.+.5
     X(2,28)=X(1,27)
     X(1,30)=X(1,27)
```

```
X(1,28)=X(1,27)-1.
X(2,29)=X(1,28)
X(1,31)=X(1,28)
X(2,31)=X(2,28)
X(2,32)=X(2,29)
X(1,33)=X(1,27)
X(1,34)=X(1,28)
X(2,34)=X(2,28)
X(2,35)=X(2,29)
X(1,36)=W3-TS31-(W3-TS31-TS32)/2.+.5
X(2,37)=X(1,36)
X(1,39)=X(1,36)
X(2,40)=X(1,36)
X(2,43)=X(1,36)
X(1,37)=X(1,36)-1.
X(2,38)=X(1,37)
X(1,40)=X(1,37)
X(2,41)=X(1,37)
X(1,43)=X(1,37)
X(2,44)=X(1,37)
X(1,42)=X(1,36)
X(1,38)=TS32
X(1,41)=TS32
X(1,44)=TS32
X(1,1)=-XINF
X(2,1)=XINF
X(2,2)=XL2
X(1,4)=XL2-W1
X(2,9)=X(1,4)
X(2,12)=X(1,4)
X(1,17)=X(1,4)
X(1,18)=X(1,4)
X(2,19)=X(1,4)
X(2,20)=X(1,4)
X(1,6)=W3
X(2,7)=W3
X(1,9)=TS32
```

```
X(1,10)=0.
X(2,10)=TS32
X(1,11)=W3
X(2,11)=XL2
X(1,12)=0.
X(1,13)=XL2
X(2,13)=XL2+TA
X(1,16)=X(2,13)
X(2,23)=X(2,13)
X(2,24)=X(2,13)
X(1,14)=-TB
X(2,14)=0.
X(1,15)=-XINF
X(2,15)=-TB
X(2,16)=XINF
X(2,17)=XL2
X(2,18)=XL2
X(1,19)=W3
X(1,20)=W3
X(1,21)=0.
X(2,21)=W3
X(1,22)=0.
X(2,22)=W3
X(1,23)=-TB
X(1,24)=-TB
X(1,25)=-XINF
X(2,25)=XINF
X(1,26)=-XINF
X(2,26)=XINF
X(3,3)=-XL3+W2
X(4,3)=-XL3+W2+D1
X(3,27)=X(4,3)
X(3,28)=X(4,3)
X(3,29)=X(4,3)
X(3,30)=X(4,3)
X(3,31)=X(4,3)
X(3,32)=X(4,3)
```

```
X(3,33)=X(4,3)
X(3,34)=X(4,3)
X(3,35)=X(4,3)
X(4,46)=XL1
X(3,47)=XL1
X(4,47)=XINF
X(3,8)=-XL3+W2+D1+DA1
X(4,27)=X(3,8)
X(4,28)=X(3,8)
X(4,29)=X(3,8)
X(4,30)=X(3,8)
X(4,31)=X(3,8)
X(4,32)=X(3,8)
X(4,33)=X(3,8)
X(4,34)=X(3,8)
X(4,35)=X(3,8)
X(4,8)=W2-TS21
X(4,5)=X(4,8)
X(3,6)=X(4,8)
X(3,7)=X(4,8)
X(3,45)=TS22
X(4,45)=XL1-D2-DA2
X(3,36)=X(4,45)
X(3,37)=X(4,45)
X(3,38)=X(4,45)
X(3,39)=X(4,45)
X(3,40)=X(4,45)
X(3,41)=X(4,45)
X(3,42)=X(4,45)
X(3,43)=X(4,45)
X(3,44)=X(4,45)
X(3,46)=XL1-D2
X(4,36)=X(3,46)
X(4,37)=X(3,46)
X(4,38)=X(3,46)
X(4,39)=X(3,46)
X(4,40)=X(3,46)
```

```
X(4,41)=X(3,46)
X(4,42)=X(3,46)
X(4,43)=X(3,46)
X(4,44)=X(3,46)
X(3,1)=-XINF
X(4,1)=-XL3+W2
X(3,2)=X(4,1)
X(3,4)=X(4,1)
X(3,12)=X(4,1)
X(3,13)=X(4,1)
X(3,14)=X(4,1)
X(3,15)=X(4,1)
X(3,16)=X(4,1)
X(3,17)=X(4,1)
X(3,18)=X(4,1)
X(3,23)=X(4,1)
X(3,24)=X(4,1)
X(3,25)=X(4,1)
X(3,26)=X(4,1)
X(4,2)=W2
X(4,4)=TS22
X(3,5)=TS22
X(4,6)=W2
X(4,7)=XL1
X(3,9)=0.
X(4,9)=TS22
X(3,10)=0.
X(4,10)=XL1
X(3,11)=W2
X(4,11)=XL1
X(4,12)=0.
X(4,13)=XL1
X(4,14)=XL1
X(4,15)=XL1
X(4,16)=XL1
X(4,17)=W2
X(4,18)=W2
```

```
X(3,19)=0.
X(4,19)=W2
X(3,20)=0.
X(4,20)=W2
X(3,21)=0.
X(4,21)=XL1
X(3,22)=0.
X(4,22)=XL1
X(4,23)=XL1
X(4,24)=XL1
X(4,25)=XL1
X(4,26)=XL1
X(5,17)=TC+HH-H2
X(5,19)=X(5,17)
X(5,21)=X(5,17)
X(6,3)=X(5,17)
X(6,8)=X(5,17)
X(6,45)=X(5,17)
X(6,46)=X(5,17)
X(6,17)=TC+HH
X(6,19)=X(6,17)
X(6,21)=X(6,17)
X(5,23)=X(6,17)
X(6,18)=TC+H1
X(6,20)=X(6,18)
X(6,22)=X(6,18)
X(5,3)=X(6,18)
X(5,8)=X(6,18)
X(5,45)=X(6,18)
X(5,46)=X(6,18)
X(5,33)=X(6,18)
X(5,34)=X(6,18)
X(5,35)=X(6,18)
X(5,42)=X(6,18)
X(5,43)=X(6,18)
X(5,44)=X(6,18)
X(5,2)=X(6,18)
```

```
X(5,4)=X(6,18)
X(5,5)=X(6,18)
X(5,6)=X(6,18)
X(5,7)=X(6,18)
X(5,9)=X(6,18)
X(5,10)=X(6,18)
X(6,11)=X(6,17)
X(6,12)=X(6,17)
X(6,13)=X(6,17)
X(6,14)=X(6,17)
X(6,23)=TC+HH+TD
X(5,25)=X(6,23)
X(6,15)=X(6,23)
X(6,16)=X(6,23)
X(5,18)=TC
X(5,20)=TC
X(5,22)=TC
X(5,24)=0.
X(6,24)=TC
X(6,25)=XINF
X(5,26)=-XINF
X(6,26)=0.
X(5,47)=-XINF
X(6,47)=XINF
X(5,27)=TC+H1+(HH-H1 ·H2)/2.+.5
X(5,28)=X(5,27)
X(5,29)=X(5,27)
X(6,30)=X(5,27)
X(6,31)=X(5,27)
X(6,32)=X(5,27)
X(5,36)=X(5,27)
X(5,37)=X(5,27)
X(5,38)=X(5,27)
X(6,39)=X(5,27)
X(6,40)=X(5,27)
X(6,41)=X(5,27)
X(5,30)=X(5,27)-1.
```

```
      X(5,31)=X(5,30)
      X(5,32)=X(5,30)
      X(6,33)=X(5,30)
      X(6,34)=X(5,30)
      X(6,35)=X(5,30)
      X(5,39)=X(5,30)
      X(5,40)=X(5,30)
      X(5,41)=X(5,30)
      X(6,42)=X(5,30)
      X(6,43)=X(5,30)
      X(6,44)=X(5,30)
      X(6,27)=TC+HH-H2
      X(6,28)=X(6,27)
      X(6,29)=X(6,27)
      X(6,36)=X(6,27)
      X(6,37)=X(6,27)
      X(6,38)=X(6,27)
      X(6,2)=X(6,27)
      X(5,4)=X(6,27)
      X(6,5)=X(6,27)
      X(6,6)=X(6,27)
      X(6,7)=X(6,27)
      X(6,9)=X(6,27)
      X(6,10)=X(6,27)
      X(5,1)=-XINF
      X(6,1)=XINF
      X(5,11)=TC
      X(5,12)=TC
      X(5,13)=TC
      X(5,14)=TC
      X(5,15)=0.
      X(5,16)=0.
      RETURN
 3001 FORMAT(19HNEG THICKNESS LEG 3)
 3002 FORMAT(19HNEG THICKNESS LEG 3)
 3003 FORMAT(19HNEG THICKNESS LEG 1)
 3004 FORMAT(16HNEG LENGTH LEG 3)
```

```
3005 FORMAT(16HNEG LENGTH LEG 1)
3006 FORMAT(16HNEG LENGTH LEG 2)
3007 FORMAT(10HNEG HEIGH
     END



     SUBROUTINE L3NCP
     DIMENSION X(6,100),IRX(6,100),H(116,10),V(116,10),INX(116,10,10)
     COMMON X,IRX,H,V,INX,IERR
     COMMON IMAX,JMAX,IHMAX,IVMAX
     COMMON XL1,XL2,XL3,W1,W2,W3,TS11,TS12,TS21,TS22,TS31,TS32,TT,D1,
    1D2,D3,DA,DB,DC,DA1,DA2,DA3,TA,TB,TC,TD,HH,H1,H2,XX
     XINF=1.E+09
     X(6,18)=XL1-HH
     X(1,20)=-XINF
     X(2,20)=-TB
     X(3,20)=-TC
     X(4,20)=XL3
     X(5,20)=-HH
     X(6,20)=XL1-HH
     X(1,21)=-TB
     X(2,21)=XINF
     X(3,21)=-TC
     X(4,21)=XL3
     X(5,21)=-XINF
     X(6,21)=-TD-HH
     X(1,61)=-XINF
     X(2,61)=-TB
     X(3,61)=-TC
     X(4,61)=XL3
     X(5,61)=-HH-TD
     X(6,61)=-HH
```

```
X(1,22)=XL2+TA
X(2,22)=XINF
X(3,22)=-TC
X(4,22)=XL3
X(5,22)=-HH
X(6,22)=XL1-HH
X(1,59)=-TB
X(2,59)=XINF
X(3,59)=-TC
X(4,59)=XL3
X(5,59)=-HH-TD
X(6,59)=-HH
X(1,29)=-TB
X(2,29)=XINF
X(3,29)=-TC
X(4,29)=XL3
X(5,29)=XL1-HH
X(6,29)=XINF
X(1,62)=-XINF
X(2,62)=-TB
X(3,62)=-TC
X(4,62)=XL3
X(5,62)=-XINF
X(6,62)=-TD-HH
X(1,64)=-XINF
X(2,64)=XINF
X(3,64)=XL3
X(4,64)=XINF
X(5,64)=-XINF
X(6,64)=XINF
X(1,63)=-XINF
X(2,63)=-TB
X(3,63)=-TC
X(4,63)=XL3
X(5,63)=XL1-HH
X(6,63)=XINF
X(1,2)=XL2-W1+TS12
```

```
X(1,3)=X(1,2)
X(1,6)=X(1,2)
X(1,9)=X(1,2)
X(1,12)=X(1,2)
X(1,13)=X(1,2)
X(2,27)=X(1,2)
X(2,18)=XL2+TA
X(1,4)=X(1,2)+(W1-TS12-TS11)/2.-.5
X(1,7)=X(1,4)
X(1,10)=X(1,4)
X(1,5)=X(1,4)+1.
X(1,8)=X(1,5)
X(1,[illegible])=X(1,5)
X(1,14)=XL2-TS11-D2
X(1,15)=TS31
X(1,16)=W3
X(1,17)=-TB
X(1,18)=-TB
X(1,19)=XL2
X(1,23)=0.
X(1,24)=0.
X(1,25)=W3
X(1,26)=XL2-TS11
X(1,27)=XL2-W1
X(1,28)=X(1,27)
X(1,30)=W3-TS32
X(1,52)=X(1,30)
X(1,31)=XL2-TS11-D2-DA2
X(1,32)=X(1,31)
X(1,33)=X(1,31)
X(1,34)=X(1,31)
X(1,35)=X(1,31)
X(1,39)=X(1,31)
X(1,38)=X(1,31)
X(1,37)=X(1,31)
X(1,36)=X(1,31)
X(1,40)=TS31
```

```
X(1,50)=TS31
X(1,51)=TS31
X(1,53)=W3
X(1,54)=0.
X(1,55)=W3
X(1,56)=W3
X(1,57)=0.
X(1,58)=0.
X(1,60)=XL2-W1
X(2,53)=X(1,60)
X(2,2)=XL2-TS11
X(2,3)=X(1,4)
X(2,6)=X(1,4)
X(2,9)=X(1,4)
X(2,4)=X(1,5)
X(2,7)=X(1,5)
X(2,10)=X(1,5)
X(2,5)=XL2-TS11
X(2,8)=X(2,5)
X(2,11)=X(2,5)
X(2,12)=X(2,5)
X(2,13)=X(2,5)
X(2,14)=X(1,2)
X(2,15)=W3-TS32
X(2,16)=XL2-W1
X(2,17)=0.
X(2,19)=XL2+TA
X(2,23)=TS31
X(2,24)=W3
X(2,25)=XL2
X(2,26)=XL2
X(2,27)=X(1,2)
X(2,28)=XL2
X(2,30)=XL2-D2-TS11-DA2
X(2,31)=XL2-TS11-D2
X(2,32)=X(2,31)
X(2,33)=X(2,31)
```

```
X(2,34)=X(2,31)
X(2,35)=X(2,31)
X(2,36)=X(2,31)
X(2,37)=X(2,31)
X(2,38)=X(2,31)
X(2,39)=X(2,31)
X(2,40)=W3-TS32
X(2,50)=X(2,40)
X(2,51)=X(2,40)
X(2,52)=W3
X(2,54)=XL2
X(2,55)=XL2
X(2,56)=XL2
X(2,57)=W3
X(2,58)=W3
X(2,60)=XL2
X(3,2)=TS21
X(3,3)=TS21
X(3,4)=TS21
X(3,5)=TS21
X(3,6)=TS21+(W2-TS21-TS22)/2.-.5
X(3,7)=X(3,6)
X(3,8)=X(3,6)
X(3,32)=X(3,6)
X(3,35)=X(3,6)
X(3,38)=X(3,6)
X(4,3)=X(3,6)
X(4,4)=X(3,6)
X(4,5)=X(3,6)
X(4,31)=X(3,6)
X(4,34)=X(3,6)
X(4,37)=X(3,6)
X(3,9)=X(3,6)+1.
X(3,10)=X(3,9)
X(3,11)=X(3,9)
X(3,33)=X(3,9)
X(3,36)=X(3,9)
```

```
X(3,39)=X(3,9)
X(4,6)=X(3,9)
X(4,7)=X(3,9)
X(4,8)=X(3,9)
X(4,32)=X(3,9)
X(4,35)=X(3,9)
X(4,38)=X(3,9)
X(3,12)=TS21
X(3,13)=TS21
X(3,14)=TS21
X(3,15)=TS21
X(3,16)=0.
X(3,17)=0.
X(3,18)=-TC
X(3,19)=0.
X(3,23)=TS21
X(3,24)=0.
X(3,25)=0.
X(3,26)=TS21
X(3,27)=TS21
X(3,28)=0.
X(3,30)=TS21
X(3,31)=TS21
X(3,34)=TS21
X(3,37)=TS21
X(3,53)=TS21
X(3,40)=W2-TS22
X(3,52)=X(3,40)
X(3,55)=X(3,40)
X(3,60)=X(3,40)
X(4,2)=X(3,40)
X(4,9)=X(3,40)
X(4,10)=X(3,40)
X(4,11)=X(3,40)
X(4,12)=X(3,40)
X(4,13)=X(3,40)
X(4,14)=X(3,40)
```

```
X(4,15)=X(3,40)
X(4,25)=X(3,40)
X(4,26)=X(3,40)
X(4,27)=X(3,40)
X(4,30)=X(3,40)
X(4,33)=X(3,40)
X(4,35)=X(3,40)
X(4,39)=X(3,40)
X(3,50)=XL3-D3
X(3,51)=XL3-TT
X(3,54)=0.
X(3,56)=W2
X(3,57)=0.
X(3,58)=TS21
X(4,1)=-TC
X(4,16)=W2
X(4,17)=XL3
X(4,18)=0.
X(4,19)=XL3
X(4,23)=XL3
X(4,24)=XL3
X(4,40)=XL3-D3-DA3
X(4,50)=XL3-TT
X(4,51)=XL3
X(4,52)=XL3
X(4,53)=W2-TS22
X(4,28)=TS21
X(4,54)=TS21
X(4,55)=W2
X(4,56)=XL3
X(4,57)=XL3
X(4,58)=XL3
X(4,60)=W2
X(5,1)=-XINF
X(5,2)=XL1-D1-FA
X(5,3)=X(5,2)-DA1
X(5,4)=X(5,3)
```

```
X(5,5)=X(5,3)
X(5,6)=X(5,3)
X(5,7)=X(5,3)
X(5,8)=X(5,3)
X(5,9)=X(5,3)
X(5,10)=X(5,3)
X(5,11)=X(5,3)
X(5,12)=-H1
X(5,13)=-HH+H2
X(5,14)=X(5,13)
X(5,15)=X(5,13)
X(5,23)=X(5,13)
X(5,26)=X(5,13)
X(5,30)=X(5,13)
X(5,37)=X(5,13)
X(5,38)=X(5,13)
X(5,39)=X(5,13)
X(5,40)=X(5,13)
X(5,50)=X(5,13)
X(5,51)=X(5,13)
X(5,52)=X(5,13)
X(5,54)=X(5,13)
X(5,16)=0.
X(5,17)=-HH
X(5,18)=-HH
X(5,19)=-HH
X(5,24)=-HH
X(5,25)=-HH
X(5,27)=-H1
X(5,28)=0.
X(5,31)=-H1-(HH-H1-H2)/2.+.5
X(5,32)=X(5,31)
X(5,33)=X(5,31)
X(6,34)=X(5,31)
X(6,35)=X(5,31)
X(6,36)=X(5,31)
X(5,41)=X(5,31)
```

```
X(5,34)=X(5,31)-1.
X(5,35)=X(5,34)
X(5,36)=X(5,34)
X(6,37)=X(5,34)
X(6,38)=X(5,34)
X(6,39)=X(5,34)
X(5,53)=-H1
X(5,55)=-HH
X(5,56)=-HH
X(5,57)=0.
X(5,58)=-H1
X(5,60)=0.
X(6,2)=XL1-HH
X(6,16)=X(6,2)
X(6,17)=X(6,2)
X(6,19)=X(6,2)
X(6,26)=X(6,2)
X(6,27)=X(6,2)
X(6,28)=X(6,2)
X(6,56)=X(6,2)
X(6,57)=X(6,2)
X(6,60)=X(6,2)
X(6,24)=-HH+H2
X(6,25)=X(6,24)
X(6,53)=0.
X(6,54)=0.
X(6,55)=0.
X(6,58)=0.
X(6,3)=X(6,2)-D1
X(6,4)=X(6,3)
X(6,5)=X(6,3)
X(6,6)=X(6,3)
X(6,7)=X(6,3)
X(6,8)=X(6,3)
X(6,9)=X(6,3)
X(6,10)=X(6,3)
X(6,11)=X(6,3)
```

```
X(6,12)=XL1-D1-DA1-HH
X(6,13)=-H1
X(6,14)=-H1
X(6,15)=-H1
X(6,23)=-H1
X(6,30)=-H1
X(6,31)=-H1
X(6,32)=-H1
X(6,33)=-H1
X(6,40)=-H1
X(6,50)=-H1
X(6,51)=-H1
X(6,52)=-H1
X(1,41)=TS31
X(2,41)=TS31+(W3-TS31-TS32)/2.-.5
X(3,41)=XL3-D3-DA3
X(4,41)=XL3-D3
X(6,41)=-H1
X(1,44)=X(1,41)
X(2,44)=X(2,41)
X(3,44)=X(3,41)
X(4,44)=X(4,41)
X(5,44)=X(5,41)-1.
X(6,44)=X(5,41)
X(1,47)=X(1,41)
X(2,47)=X(2,41)
X(3,47)=X(3,41)
X(4,47)=X(4,41)
X(5,47)=-HH+H2
X(6,47)=X(5,44)
X(1,42)=X(2,41)
X(2,42)=X(2,41)+1.
X(3,42)=X(3,41)
X(4,42)=X(4,41)
X(5,42)=X(5,41)
X(6,42)=X(6,41)
X(1,45)=X(2,41)
```

```
X(2,45)=X(2,41)+1.
X(3,45)=X(3,44)
X(4,45)=X(4,44)
X(5,45)=X(5,44)
X(6,45)=X(6,44)
X(1,48)=X(2,41)
X(2,48)=X(2,41)+1.
X(3,48)=X(3,47)
X(4,48)=X(4,47)
X(5,48)=X(5,47)
X(6,48)=X(6,47)
X(1,43)=X(2,42)
X(2,43)=W3-TS32
X(3,43)=X(3,41)
X(4,43)=X(4,41)
X(5,43)=X(5,41)
X(6,43)=X(6,41)
X(1,46)=X(2,42)
X(2,46)=W3-TS32
X(3,46)=X(3,44)
X(4,46)=X(4,44)
X(5,46)=X(5,44)
X(6,46)=X(6,44)
X(1,49)=X(2,42)
X(2,49)=W3-TS32
X(3,49)=X(3,47)
X(4,49)=X(4,47)
X(5,49)=X(5,47)
X(6,49)=X(6,47)
X(2, 1)=XINF
X(6, 1)=XINF
X(1, 1)=-XINF
X(3, 1)=-XINF
RETURN
END
```

Table II. Physical Parameters of Ducts

Parameters	Subroutine		
	L2 (Two-Legged)	L3Z (Three-Legged Coplanar)	L3NCP (Three-Legged Non-Coplanar)
First Card			
Columns 9 & 10[1]	43	47	64
Column 20[2]	1	2	3
XL1	200 cm[3]	167 cm[3]	150 cm[3]
XL2	190	151	210
XL3	0	141	200
W1	92	72.39	100
W2	100	80.01	61
W3	0	72.39	62
TS11	29	16.51	35
TS12	35.6	27.94	36
TS21	35.6	16.51	16
TS22	35.6	35.56	17
TS31	0	27.94	16
TS32	0	16.51	17
TT	1	0	1
D1	41.0	10	38
D2	41.0	9	84
D3	0	0	51
DA	1.0	0	0
DB	1.0	0	0
DC	1.0	0	0
DA1	0	1.0	1.0
DA2	0	1.0	1.0
DA3	0	0	1.0
TA	61	61	60
TB	61	61	61
TC	61	61	59
TD	61	61	60
HH	60.9	60.96	73
H1	16.5	16.51	28
H2	16.5	16.51	17
XX	0	0	0

1/ Total number of regions

2/ Subroutine number

3/ Duct dimensions

Table III. ADONIS Input Cards For Two-Legged Duct

```
-0.10000E 10 0.10000E 10-0.10000E 10-0.61000E 02-0.10000E 10 0.10000E 10
 0.15900E 03 0.20000E 03 0.29000E 02 0.56400E 02-0.44400E 02-0.16500E 02
 0.15800E 03 0.15900E 03 0.43200E 02 0.56400E 02-0.44400E 02-0.30950E 02
 0.15800E 03 0.15900E 03 0.42200E 02 0.43200E 02-0.44400E 02-0.30950E 02
 0.15800E 03 0.15900E 03 0.29000E 02 0.42200E 02-0.44400E 02-0.30950E 02
 0.15800E 03 0.15900E 03 0.43200E 02 0.56400E 02-0.30950E 02-0.29950E 02
 0.15800E 03 0.15900E 03 0.42200E 02 0.43200E 02-0.30950E 02-0.29950E 02
 0.15800E 03 0.15900E 03 0.29000E 02 0.42200E 02-0.30950E 02-0.29950E 02
 0.15800E 03 0.15900E 03 0.43200E 02 0.56400E 02-0.29950E 02-0.16500E 02
 0.15800E 03 0.15900E 03 0.42200E 02 0.43200E 02-0.29950E 02-0.16500E 02
 0.15800E 03 0.15900E 03 0.29000E 02 0.42200E 02-0.29950E 02-0.16500E 02
 0.64400E 02 0.15800E 03 0.29000E 02 0.56400E 02-0.44400E 02-0.16500E 02
 0.35600E 02 0.64400E 02 0.29000E 02 0.56400E 02-0.44400E 02-0.16500E 02
 0.35600E 02 0.64400E 02 0.56400E 02 0.14800E 03-0.44400E 02-0.16500E 02
 0.50500E 02 0.64400E 02 0.14800E 03 0.14900E 03-0.44400E 02-0.30950E 02
 0.49500E 02 0.50500E 02 0.14800E 03 0.14900E 03-0.44400E 02-0.30950E 02
 0.35600E 02 0.49500E 02 0.14800E 03 0.14900E 03-0.44400E 02-0.30950E 02
 0.50500E 02 0.64400E 02 0.14800E 03 0.14900E 03-0.30950E 02-0.29950E 02
 0.49500E 02 0.50500E 02 0.14800E 03 0.14900E 03-0.30950E 02-0.29950E 02
 0.35600E 02 0.49500E 02 0.14800E 03 0.14900E 03-0.30950E 02-0.29950E 02
 0.50500E 02 0.64400E 02 0.14800E 03 0.14900E 03-0.29950E 02-0.16500E 02
 0.49500E 02 0.50500E 02 0.14800E 03 0.14900E 03-0.29950E 02-0.16500E 02
 0.35600E 02 0.49500E 02 0.14800E 03 0.14900E 03-0.29950E 02-0.16500E 02
 0.35600E 02 0.64400E 02 0.14900E 03 0.18900E 03-0.44400E 02-0.16500E 02
 0.35600E 02 0.64400E 02 0.18900E 03 0.19000E 03-0.44400E 02-0.16500E 02
 0.          0.20000E 03 0.          0.92000E 02-0.16500E 02 0.
 0.64400E 02 0.20000E 03 0.56400E 02 0.92000E 02-0.44400E 02-0.16500E 02
 0.          0.20000E 03 0.          0.92000E 02-0.60900E 02-0.44400E 02
 0.          0.20000E 03 0.          0.29000E 02-0.44400E 02-0.16500E 02
 0.          0.10000E 03 0.92000E 02 0.19000E 03-0.16500E 02 0.
 0.64400E 02 0.10000E 03 0.92000E 02 0.19000E 03-0.44400E 02-0.16500E 02
 0.          0.10000E 03 0.92000E 02 0.19000E 03-0.60900E 02-0.44400E 02
 0.          0.35600E 02 0.29000E 02 0.19000E 03-0.44400E 02-0.16500E 02
 0.10000E 03 0.20000E 03 0.92000E 02 0.19000E 03-0.60900E 02 0.
```

```
-0.61000E 02 0.20000E 03-0.61000E 02 0.19000E 03 0.                       0.61000E 02
-0.61000E 02 0.20000E 03-0.61000E 02 0.19000E 03-0.12190E 03-0.60900E 02
-0.61000E 02 0.20000E 03-0.61000E 02 0.                      -0.60900E 02 0.
-0.61000E 02 0.          0.          0.19000E 03-0.60900E 02 0.
-0.10000E 10 0.20000E 03-0.61000E 02 0.19000E 03 0.61000E 02 0.10000E 10
-0.10000E 10 0.20000E 03-0.61000E 02 0.19000E 03-0.10000E 10-0.12190E 03
 0.20000E 03 0.10000E 10-0.61000E 02 0.19000E 03-0.10000E 10 0.10000E 10
-0.10000E 10-0.61000E 02-0.61000E 02 0.19000E 03-0.12190E 03 0.61000E 02
-0.10000E 10 0.10000E 10 0.19000E 03 0.10000E 10-0.10000E 10 0.10000E 10
          1           1           1          -1           1           1
         -2          41          29          27          28          26
         12           2           4          27          28           6
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 190.00
 190.00
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  64.40
 148.00 149.00 189.00 190.00
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 35.56
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121.96
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105.45					
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78.61	134.49				
63.50	157.00				
157.00	158.00	167.00			
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105.45					
72.39	78.61				
72.39	78.61				
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